CATASTROPHE AND CONTROL:
HOW TECHNOLOGICAL DISASTERS ENHANCE DEMOCRACY

by

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Submitted to the Program in Science, Technology, and Society on July 26, 1994, in partial fulfillment of the requirements for the degree of Doctor of Philosophy in History and Social Study of Science and Technology at the Massachusetts Institute of Technology

ABSTRACT

As occasions when large, complex, well-entrenched technological systems have gone catastrophically "out of control," disasters such as the Bhopal gas leak and the Three Mile Island and Chernobyl meltdowns have been moments of both technological and political instability in industrialized societies. Through the enormous media attention they generate, control breakdowns like these have taught lay citizens how complex technologies work and how technological and political control are distributed at the local and national levels. Citizens have used this information to press for safety improvements and for more participatory ways of choosing, building, and managing large technological systems.

The study culls newspaper records, accident reports, social science data, and other sources to reconstruct the origins and outcomes of five serious technological disasters of recent decades: the 1965 power failure in the Northeastern United States, the 1977 blackout in New York City, the 1979 meltdown at the Three Mile Island nuclear plant in Pennsylvania, the 1984 methyl isocyanate leak at a Union Carbide chemical plant in Bhopal, India, and the 1986 explosion and meltdown at the Chernobyl atomic energy station in Ukraine. Each of these disasters led to the public disclosure of previously unavailable information about the technical, organizational, and political nature of the systems in question. Analysis focuses on the ways in which this information shaped citizens' movements for technological change and for greater citizen participation in decision-making about hazardous technologies.

The study concludes that control breakdowns in large technological systems have educated and radicalized many lay citizens, enabling them to challenge both existing technological plans and the expertise and authority of the people who carry them out. The author detects in this development a new cultural undercurrent of "technological citizenship" characterized by greater knowledge of, and skepticism toward, the complex systems that permeate modern societies.

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TABLE OF CONTENTS

Abstract 3

Acknowledgments 5

Introduction **The Meaning of Technological Catastrophes** 11

A Look Forward, 26.

Chapter 1 **Control Room Blues**
Large Technological Systems and the
Embrittled Metaphor of Cybernetic Control 29

Why Large-Scale System Disasters? 36; Large Systems, Complexity, and the Limits of Cybernetic Control, 46; The Politics of Large Technological Systems, 59; Catastrophes: A Chink in the Armor, 71; Risk, Social Movements, and NIMBYism, 79.

Chapter 2 **The Precious Dark**
The New York City Blackouts of
1965 and 1977 91

The Great Northeast Power Failure, 100; Relay Race, 107; The Blackout Experience, 108; Escaping the "Prison Farm of Modern Technology," 113; And Then There Was Light, 118; Dependence and Interconnection, 121; The 1977 Blackout, 130; Blackout Looting, 135; Turning to Decentralized Energy, 141; The Machine Stops, 146.

Chapter 3 **The Billion-Dollar Mausoleum**
Three Mile Island and the Slow Demise
of Commercial Nuclear Power 151

The Cold War's LWR Legacy, 159; "The Thing Was Simply Uncorked," 171; "All Hell Broke Loose," 182; Shifting Ground, 191; "Moment of Truth," 201; Walking Away from Nuclear Power, Slowly, 208.

continued on next page

Chapter 4 **Runaway Reaction**
Knowledge, Control, and
Danger After Bhopal........ 221

Organic Chemistry Comes to Bhopal, 228; Poisoned Air, 238; Knowledge, Control, and Danger, 251; Indian Citizens Respond, 256; "It Can Happen Here," 267; Winning and Using the Right to Know, 277; The World After Bhopal, 290.

Chapter 5 **A Crimson Incandescence**
Chernobyl and the Fall of
the Soviet Union........ 297

Technological Gigantism, 312; Irregular Experiment, Normal Accident, 319; An Assault on Health and Nature, 329; Soviet Nuclear Power After Chernobyl, 337; The Fission of the Soviet State, 349; "The Beginning of Wisdom," 360.

Chapter 6 **Technological Citizenship**........ 365

Challenges to Technological Design, 376; Challenges to Technical Authority, 380; Expanding Definitions of Citizenship, 384; Technological Citizenship, 393.

Bibliography........ 401

Introduction

THE MEANING OF TECHNOLOGICAL DISASTERS

The traffic moves around with care,
But we remain, touching a wound
That opens to our richest horror.
Already old, the question Who shall die?
Becomes unspoken Who is innocent?
For death in war is done by hands;
Suicide has cause and stillbirth, logic;
And cancer, simple as a flower, blooms.
But this invites the occult mind,
Cancels our physics with a sneer,
And spatters all we knew of denouement
Across the expedient and wicked stones.

—from Karl Shapiro
"Auto Wreck"[1]

Everyone is intrigued by disasters. News consumers sometimes complain that earthquakes, floods, fires, bombings, plane crashes, factory explosions, oil spills and the like crowd out more humane and uplifting stories, but the truth is that when something terrible happens, people want to know about it. This is why, from the journalist's point of view, disasters have always been ideal news events. Sudden, unexpected, deadly, they disrupt the routines of workaday life and remind us that no matter how much control we think we exercise over nature and over our technology, it can all crumble in minutes.

Disasters that get enough attention earn their own shorthand tags in the history books, like the Massachusetts Blizzard of 1978, the Loma Prieta earthquake of 1989, and the Black Monday stock market crash of 1987. My argument begins with the fact that a striking number of the named disasters of recent years, the ones everybody knows about, have been *technological* rather than natural in origin. Think about it for a moment: Twenty years hence, are not Love Canal, Three Mile Island, Bhopal, Chernobyl, the *Challenger* explosion, and the *Exxon Valdez* likely to be remembered just as vividly as, say, Hurricane Andrew in 1992 or the Mississippi River Valley flooding of 1993? Whatever is going on -- whether the engineering profession has simply had a run of extremely bad luck, or whether, as I will argue, more systemic problems are at work -- the news pages of the past two decades have provided nourishment for the idea that "technological disasters" are a distinct kind of crisis, different from natural disasters and other categories of carnage, with their own historical causes and implications.

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[1] Karl Shapiro, *Selected Poems* (New York: Random House, 1968).

Kai Erikson, the sociologist, has called technological disasters "a new species of trouble," but they are not new.[2] Gruesome train wrecks and steamship explosions killed hundreds during the nineteenth century, and industrialism's march in the twentieth has been regularly punctuated by mining accidents, dam breaks, mass poisonings, and the like. The sinking of the *Titanic* in 1912, the explosion of the *Hindenburg* in 1937, and the collapse of the Tacoma Narrows bridge in 1940 all linger in the public memory as spectacular examples of technological failure. What *is* different about the disasters of recent years is that they have received such intense and extended media coverage, each intensifying the publicity surrounding the next, that many observers have begun to search for some kind of unified explanation. Why are our machines doing this to us, and what can be done about it?

One good explanation has already been offered. In *Normal Accidents: Living with High-Risk Technologies*, sociologist Charles Perrow laid out a way of seeing serious accidents as the nearly inevitable outcomes of complex technological undertakings. Though Perrow published his book in 1984, before the gas disaster in Bhopal, the Chernobyl meltdown, and the *Challenger* explosion, it explains those newer catastrophes as accurately as it did Three Mile Island and Perrow's other case studies. *Normal Accidents* is essential reading today for industrial managers, organizational sociologists, historians of technology, and interested lay people alike, because it shows that a major strategy engineers have used in this century to keep hazardous technologies under control -- multiple layers of "fail-safe" backup devices -- often adds a dangerous level of unpredictability to the system as a whole. In fact, the only thing we can confidently predict about large, complex technologies like nuclear power, chemical manufacturing, and manned space flight is that they will occasionally be struck by massive "system accidents" in which design oversights, mechanical malfunctions, and human errors interact to defeat the built-in safeguards. "We have produced designs so complicated that we cannot anticipate all the possible interactions of the inevitable failures; we add safety devices that are deceived or avoided by hidden paths in the systems," writes Perrow. "We might begin to learn [from these ineffective technical 'fixes'] that of all the glorious possibilities out there to reach for, some are going to be beyond our grasp in catastrophic ways."[3]

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[2] See Erikson, Kai T., "Toxic Reckoning: Business Faces a New Kind of Fear," *Harvard Business Review* (Jan.-Feb., 1990) 118-126.

The particulars of Perrow's theory accord so well with common sense that nothing has come along to replace them in the worlds of professional risk assessment and industrial sociology, and neither will I attempt to do so here. The rest of my argument hinges, instead, on the difference between *explanation* and *meaning*. Perrow has set down in plain English a way of understanding the causes of technological disasters: their logical development from prior decisions about designs, processes, materials, and operating practices. While these causes are interesting and important in themselves (and I will spend a good bit of time in the following pages tracing the origins of several spectacular disasters), they do not necessarily reveal the larger historical and political significance of technological catastrophes. The severe disasters of recent years, I will argue, share hidden qualities beyond the fact that they can all be attributed to unforeseen interactions between supposedly fail-safe system components. Indirectly, these events are telling us something about the very way technology fits into modern life. This study will be a search for the *cultural and political meanings* of technological catastrophes: for what they convey about the customs, assumptions, and governing styles of modern industrial societies, and how all of these may be changing as a result of the catastrophes themselves.

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[3] Charles Perrow, *Normal Accidents: Living with High-Risk Technologies* (New York: Basic Books, 1984) 11.

An old idea about the meaning of technological disasters, though not a very thoroughly analyzed one, is that technology has somehow grown beyond our control. Disasters are seen as an almost willful expression of mechanical defiance, perhaps even punishment for humanity's hubris. In his biography of the late physicist Richard Feynman, who served on the presidential commission investigating the *Challenger* accident, science writer James Gleick put this idea as follows:

> Machinery out of control...After the nuclear accident at Three Mile Island, Pennsylvania, and the chemical disaster at Bhopal, India, the space-shuttle explosion seemed a final confirmation that technology had broken free of human reins. Did nothing work any more? The dream of technology that held sway over the America of Feynman's childhood had given way to a sense of technology as not just a villain but an inept villain. Nuclear power plants, once offering the innocent promise of inexhaustible power, had become menacing symbols on the landscape. Automobiles, computers, simple household appliances, or giant industrial machines -- all seemed unpredictable, dangerous, untrustworthy. The society of engineers, so hopeful in the America of Feynman's childhood, had given way to a technocracy, bloated and overconfident, collapsing under the weight of its own byzantine devices. That was one message read in the image replayed hundreds of times that day on millions of television screens -- the fragmenting smoke cloud, the twin

> rockets veering apart like Roman candles.[4]

Little is overdramatized in this portrait of American attitudes toward technology circa 1986. I recall my own shock, grief, and suspicion on the day of the *Challenger* explosion; I was nineteen at the time, not old enough to remember Vietnam or Watergate but steeped in the legend of the Apollo missions, and my consequent sense of disillusionment with American achievements like the space program eventually led me to this very study.

Yet there is something incomplete about this way of understanding technological disasters. Most naively, it assigns a mystical degree of autonomy to machines. Technological artifacts cannot themselves be villains, even inept ones, except in science fiction. While it is tempting to believe that machines break down whenever they feel like it, or worse, that they act with malice aforethought, this is ultimately just a way of ignoring the human agency at work behind disastrous failures.

The concern hinted at, but left unexplored, by the lament of machinery-out-of-control is that the *organizations* that run large technological systems are what have truly threatened to grow beyond any form of democratic governance. There is much evidence that the most important cultural meanings of technological disasters lay in *what they reveal about the way technological control is distributed through society, and in how they help change that distribution.*

I have just introduced two slippery words, "democratic" and "control," and before continuing I must explain in a preliminary way how I believe each relates to technology. While this study's immediate focus is on a set of recent technological disasters and their causes and political implications, I approach these episodes as useful prisms on a broader question: What forms can citizenship take in societies that have been transformed by the presence of powerful, complex, interconnected technological systems? Among the most eloquent of the many writers who have grappled with this issue are Langdon Winner and Richard Sclove, both political scientists. The two have urged their fellow thinkers in the field of science and technology studies to eschew elaborate policy prescriptions and pay more attention to the "nuts and bolts" of democratic politics in advanced industrial societies:

---

[4] James Gleick, *Genius: The Life and Science of Richard Feynman* (New York: Pantheon Books, 1992) 416.

> **Winner:** Because technological things so often become central features in widely shared arrangements and conditions of life in contemporary society, there is an urgent need to think about them in a political light. Rather than continue the technocratic pattern in which philosophers advise a narrowly defined set of decision-makers about ethical subtleties, today's thinkers would do better to re-examine the role of the public in matters of this kind. How can and should democratic citizenry participate in decision making about technology?[5]
>
> **Sclove:** An engaged citizenry must become critically involved with the choice, governance, and even design of technological artifacts and practices, and committed specifically to adopting only those technologies that are themselves compatible in their design with reproducing through time the society's democratic nature. Or else there can be no democracy...A special responsibility of scholars and academics...is to select socially useful research topics...[including] evaluating local, translocal, and international efforts to democratize technological design and politics.[6]

An objective look at several prominent technological disasters of the recent past can, I believe, help to identify models of citizenship better attuned to the political challenges created by today's technological environment.

"Democratic" technologies, in this context, would be those that promote, or at least do not suppress, people's ability to govern themselves in the sense intended by the authors of the U.S. Constitution. As Sclove explains, "Technologies help to re-structure social relations. But notice that [they] tend to do this *independently of their nominally intended purposes.*"[7] Henry Ford, for example, could not have foreseen that the character of urban, suburban, and rural regions in the United States and elsewhere would be transformed by mass ownership of automobiles, but nonetheless this was one major result of his pioneering work in assembly-line auto manufacturing. Deciding whether a technology is democratic or undemocratic, therefore, means uncovering all of the ways in which it may enable or impair people's basic rights to decide how and where they want to live, free from undue government interference and threats to their health and safety. A democratic technological order is one in which all citizens can participate equally in such decisions.

---

[5] Langdon Winner, "Citizen Virtues in a Technological Order," *Inquiry* (35) 343.

[6] Richard Sclove, "The Nuts and Bolts of Democracy: Democratic Theory and Technological Design," a paper delivered at the 1987 Annual Meeting of the American Political Science Association, pp. 1, 20-21. Copy provided courtesy of the author.

"Control," as I want to use it here, is a slightly more complex idea. The word has its origins in the medieval Latin verb *contrarotulare,* "to compare against the rolls" or history books, and in the French *contrerolles,* from the early capitalist practice of double-entry bookkeeping on "counter-rolls."[8] From there the word spread into politics, science, and literature, where by Shakespeare's time it had come to mean "To exercise restraint or direction upon free action; to hold sway over, exercise power or authority over; to dominate, command"[9]: in essence, it is the opposite of self-government and democracy as these concepts would come to be understood by the late eighteenth century.

During the nineteeth and twentieth centuries, as humans and machines started working together on many kinds of tasks, "control" acquired important new technological meanings. The following passage, written by three industrial engineers, tells this story and shows how the term is now used:

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[7] Richard Sclove, "Technological Politics As If Democracy Really Mattered," in Michael Shuman and Julia Sweig, eds., *Technology for the Common Good* (Washington: Institute for Policy Studies, 1993) 58.

[8] James R. Beniger, *The Control Revolution: Technological and Economic Origins of the Information Society* (Cambridge, Mass.: Harvard University Press, 1986) 8.

[9] *Oxford English Dictionary,* Compact Edition, Vol. 1, 542.

> A human-machine system requires the definition of roles both for the human and the machine. In classical human-machine control, the human operator manipulated the controls of the actuators and machines directly, and could see either the results of those manipulations on the state of the process or product, or at least a very direct representation of them by means of machine sensors and displays. With the coming of automation, and particularly with the rise of computer control, the situation has changed. Because so much of the control loop can now be given to the machines, and also because of the increasingly hazardous operations involved in high technology, the human is becoming ever less tightly coupled to the process he or she controls...[For example] in industrial operations such as nuclear power plants there are parts of the plant which humans cannot enter on pain of death due to the radiation. Hence the human now exercises control of not the process itself, but through a machine of some kind which controls the process and purveys information to the human.[10]

Control, in this sense, supplements and extends human abilities, allowing motion and energy to be harnessed in ever-greater quantities. But as Sclove points out, advances in technology bring with them changes in the distribution of decision-making power implicit in all technological systems, and these changes may not necessarily proceed toward any democratically defined social good. Historians of the U.S. space program, for example, have documented how NASA's decision to spend tens of billions of dollars developing the space shuttle was driven not by valid scientific or economic rationale but by military pressures and the need for a post-Apollo mission that would allow the agency to maintain its large, expensive research-and-development bureaucracy.[11]

When technological systems begin to readjust their political and economic environments according to their own internal requirements -- and particularly when the technical processes employed are so hazardous that extraordinary social and technical measures must be taken to guard against the potentially catastrophic consequences of a breakdown -- then the political and technological meanings of "control" begin to blend and reinforce one another. The power to design, build, and operate technological systems encroaches on the free action of individual citizens, becoming a form of governing authority. It is not unusual nowadays to hear citizens complaining that they "have no control" over what goes on at the nuclear power plant or the hazardous waste incinerator down the road. They are expressing a dual frustration: that the technology is run by people, organizations, and machines they do not know or trust *and* that they were not included in decisions about whether, where, and how the installation was to be built in the first place.

---

[10] Neville Moray, William R. Ferrell, and William B. Rouse, *Robotics, Control and Society: Essays in Honor of Thomas B. Sheridan* (London: Taylor & Francis, 1990) 101.

[11] See, for example, Joseph J. Trento, *Prescription for Disaster: From the Glory of Apollo to the Betrayal of the Shuttle* (New York: Crown Publishers, Inc., 1987).

Now I may return to my previous point, which is central to this study. Technological disasters, by definition, involve the breakdown of control over highly energetic processes. (If control were never lost, nothing unexpected or accidental would ever happen, and if large amounts of energy were not involved, the consequences of an accident would not be disastrous; at stake is the difference between a fender-bender and a DC-10 slamming into the ground at high speed.) The most basic lesson of a disaster, then, is that control is not immutable. It can be gained or let slip, hoarded or shared. Because technological disasters are news, they call attention to those who have control and how they lose it. At the same time, disasters show that the citizens who suffer most from sudden releases of energy are often those who have the least initial control; and citizens, whether they live under democratic or authoritarian regimes, can get very angry about the vulnerability that goes along with this kind of powerlessness.

But in a disaster, fortuitously, there is a kind of democracy of powerlessness, since the people in charge of the technology, having proved unable to prevent the catastrophe, lose much of their claim to expertise and authority. They may also forfeit the public confidence and trust which customarily shelter them from scrutiny by outsiders. *A technological catastrophe, therefore, can create the conditions for a process of negotiation over how control is to be shared in the future.* As they try to reestablish technical control, the owners and managers of the system that failed are likely to be forced to cede some political control to those outside the initial technical control process, and they may even find that their technology is no longer wanted by the general public. When control over technology is shown to be synonymous with control over people's health, safety, and freedom, then technological catastrophe -- the ultimate control breakdown -- can be a democratizing wedge.

Demonstrating disaster's democracy-enhancing power in practice will be this study's main goal. Though I draw on a mix of methods and styles, my intellectual home is in history and journalism, and so what I mainly have to offer by way of evidence are narratives. These are documented accounts of some of the most important large technological systems of our day (electrical power distribution, nuclear energy, and chemical manufacturing) and the corporations, agencies, workers, and citizens who build, regulate, run, and live among them. In each case, of course, the crux of the story is a devastating technological failure that leads the press, citizens, and their representatives in government to question the nature of the technology itself, including its inherent hazards and its political character.

After the Bhopal gas disaster killed some 3,000 people in India, the editors of *The New Yorker* wrote that "what truly grips us [in accounts of technological catastrophe] is not so much the numbers as the spectacle of suddenly vanishing competence, of men utterly routed by technology, of fail-safe systems failing with a logic as inexorable as it was once -- indeed, right up until the very moment -- unforeseeable. And the spectacle haunts us because it seems to carry allegorical import, like the whispery omen of a hovering future."[12] If non-fictional events like the ones I will retell here can indeed be allegorical, then one of the truths they express is that no technology is so safe and essential, and no technological organization so dependable and pure of intent, that democratic checks and controls may reliably be dispensed with. Citizens, as they come to this realization, are devising new and more effective ways to become involved in ethical and political decisions affecting their technological environments.

Admittedly, this way of talking about disasters may fasten on the exceptional. For one, the customary cultural response to technological failure has little to do with direct public participation. It is, instead, to demand that engineers isolate and correct the cause of the failure so that life may continue free of this hazard in the future. This response may be called "meliorist," a word coined by the nineteenth-century novelist George Eliot to describe her belief that the world may be made better through human effort (Latin *melior* = "better"), and it is one of the basic doctrines underlying the tremendous scientific and technological successes of the last three centuries. If architects and engineers were not able to learn from their mistakes and to try again, then the great cathedrals of Europe, the Golden Gate Bridge, and the Boeing 747 would not exist today. As the engineer Samuel Florman once wrote, "The colossal works of man are no more inherently vulgar than the small works are inherently petty."[13]

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[12] "Notes and Comment," *The New Yorker* (Feb. 18, 1985) 23-30.

But making a technology *bigger* and *more reliable* does not necessarily make it more *socially acceptable.* What I want to chronicle here are a few of the occasions in history when at least some citizens have concluded that an automatic meliorist response to disaster would conflict with other deeply-held values, including safety, freedom, and democratic rule. Neighbors of the Three Mile Island nuclear plant in Pennsylvania, for example, were unhappy to learn after the meltdown inside the Unit 2 reactor there that the plant's owners intended to continue operating the (undamaged) Unit 1 reactor. They were angry enough to spend six years battling the utility and the federal Nuclear Regulatory Commission to prevent the restart. Though they were ultimately not successful, the battle alerted millions of citizens to the fact that large technological systems like nuclear energy can take on an internal momentum and direction that grow increasingly disconnected from democratically-formulated social goals (see Chapter 3).

From their earliest years, children are taught to appreciate disasters. Lullabies, fairy tales, and nursery rhymes contain some of our culture's most garish depictions of death, destruction, and chaos. Play, too, often revolves around control and its antithesis: toddlers build towers of blocks for the sheer pleasure of knocking them down at the end, and older children construct houses of cards in anticipation of that excruciating, thrilling moment when the whole structure flutters back to flatness. Is it any wonder, then, that motorists passing the scene of an automobile accident do not look away but gaze attentively at the twisted, smoking wreck, or that thousands of witnesses gather whenever an old building is being demolished, or that the same gruesome images appear over and over on our television screens after a catastrophe like the *Challenger* explosion? An ingrained appetite for spectacle is part of what draws people to disaster.[14]

---

[13] Samuel C. Florman, "Small is Dubious," *Harper's Magazine* (Aug., 1977) 10-12.

This fascination with catastrophe can lead citizens to a more engaged, inquisitive stance toward the important technological failures of our day. The Oxford English Dictionary defines *disaster* as "anything that befalls of ruinous or distressing nature; a sudden or great misfortune, mishap, or misadventure: a calamity," but to settle for this definition would be unimaginative. I do not mean to suggest that technological failures should be enjoyed, but perhaps they should, in a sense, be *inhabited*. Curious minds may profit from the study of breakdowns precisely because they are out of the ordinary. As Thomas Drabek, a sociologist and disaster researcher, has pointed out, "Disaster events represent unique laboratories; they are in this sense ethically acceptable natural experiments."[15] This does not mean that it is ethical to *set up* technological disasters: only that it is ethically required to extract all possible knowledge about their causes and implications when they do happen. The facts brought to light can be used not only to prevent recurrences, but to map out the ways in which society depends on the technology in question, the extent to which those needs are legitimate, and how they might be met more safely and fairly in the future.

While this is most importantly a scholarly study, I have tried to include elements that will interest many groups of readers. For nonspecialists who may be curious about the disasters themselves, I hope to render an accurate picture of their historical antecedents, technical development, and political outcomes. For disaster buffs or social scientists studying catastrophes, on the other hand, I hope to bring together familiar details in new and useful ways. For business people or industrial managers who may already be versed in theories like Perrow's, I hope to offer a broader, more contextualized view of technological disasters, one that may help them see the changes their own firms are facing as part of a larger trend toward citizen assertiveness. For community activists and others who are concerned about technological threats to their own health and safety, I hope to point out a few encouraging examples of democratic reform flowing from disasters, and also to offer a review of the barriers to change. For my fellow students in the fledgling field of "science and technology studies," finally, I hope to provide a worthwhile example of scholarship that is beholden to no particular academic discipline but that draws on useful ingredients of many.

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[14] On the latter theme, Don DeLillo's 1985 novel *White Noise* is instructive.

[15] Thomas E. Drabek, *Human System Responses to Disaster: An Inventory of Sociological Findings* (New York: Springer-Verlag, 1986) 420.

A Look Forward

Chapter 1 considers in more detail several of the concepts just proposed, asking: What is a technological disaster? What are some of the political outcomes of the spread of large technological systems in modern industrial societies? And why are sudden, severe breakdowns within these systems worth examining separately from other kinds of disasters? We will see why large-system disasters are unlikely to abate in the future and why, ironically, they may be the best way for people to learn about the architecture of the technologies on which they depend. "If there is such a thing as technological citizenship, then disasters serve alongside consumer experience as schools of this type of responsible participation," writes Victor McElheny.[16]

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[16] Personal communication , Feb. 23, 1994.

Chapter 2 is the first substantive case study. It tells the story of the two massive electrical blackouts endured by the residents of New York City in 1965 and 1977, the first merely surprising, the second genuinely disastrous. The blackouts showed one of the most ubiquitous technologies of modern life, the electrical grid, to be frighteningly vulnerable to breakdown. While the failures spurred electrical utilities to take steps to enhance reliability, they also forced New Yorkers and others to recognize their extraordinary dependence on this centralized, monopolistic technological system. One result is today's growing emphasis on smaller, more distributed energy technologies.

Chapter 3 reviews the nuclear meltdown at Three Mile Island in 1979, an event that killed no one (as yet) but that has become, along with the *Challenger* explosion, the archetypal American technological disaster. We will see how the confusion and contradictory information surrounding the meltdown helped destroy the U.S. nuclear industry's credibility in the public mind, and how the accident led to a vigorous political movement for the TMI plant's abandonment. This local movement failed, but the dreary national future of nuclear power testifies to the power of a disaster to help seal the fate of an expensive and hazardous technology.

Chapter 4 details what was probably the most gruesome industrial catastrophe in history, the 1984 methyl isocyanate leak at the Union Carbide pesticide factory in Bhopal, India. Central to that accident was a shocking lack of awareness of the plant's hazards among almost all of those concerned -- including Union Carbide executives, workers at the plant, and especially the thousands of gas victims. The disaster underscored the links between knowledge, control, and danger, and greatly boosted the movement -- in the United States -- for "right-to-know" laws guaranteeing public involvement in the management of chemical hazards.

Chapter 5, on the 1986 explosion at the Chernobyl nuclear power station in Ukraine, examines how the catastrophic failure of a state-operated technology helped undermine that state's legitimacy. We will see how the Chernobyl accident, coming on the cusp of revolutionary (or counterrevolutionary) changes in Soviet political life, contributed in crucial ways to the downfall of the Communist Party and helped set the former republics on a tentative path toward popular rule.

Chapter 6, finally, interprets the citizens' movements that follow technological disasters as makeshift yet vital substitutes for democracy in societies where, thanks partly to modern technology itself, traditional forms of representative democracy have failed. Disasters foster public skepticism toward large technological systems and those who claim to "control" them. This skepticism, I conclude, is a necessary ingredient in any truly participatory technological order.

Chapter 1

CONTROL ROOM BLUES

Large Technological Systems and the Embrittled Metaphor of Cybernetic Control

The flow of new and useful information about how technological systems fail is in no danger of drying up. Breakdowns, disruptions, and full-blown disasters involving complex technologies and the complex organizations that manage them occur today with fateful regularity, as a few examples from recent headlines show:

- July 3, 1988. The cruiser U.S.S. *Vincennes*, on patrol in the Persian Gulf to help protect U.S. oil-shipping interests during a tense phase of the Iran-Iraq war, launches two surface-to-air missiles against an Iranian passenger jet, killing all 290 people aboard. Flaws in the ship's $600 million Aegis computerized defense system led crew members to misidentify the plane as a hostile F-14 fighter.[1]

- January 16, 1990. A faulty switch at AT&T's New York City switching center triggers a hidden error in the company's new signaling software, shutting down primary and backup computers at other centers across the country. Of the 138 million long-distance calls attempted that day, 70 million are turned away. AT&T customers suffer business losses amounting to hundreds of millions of dollars.[2]

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[1] An excellent rendition of the *Vincennes* incident is available in Leonard Lee, *The Day the Phones Stopped: How People Get Hurt When Computers Go Wrong* (New York: Donald I. Fine, Inc., 1992), 214-240. Another recent book rich in descriptions of interesting technological failures is Steven Casey's *Set Phasers on Stun, And Other True Tales of Design, Technology, and Human Error* (Santa Barbara, Calif.: Aegean Publishing Company, 1993).

- September 17, 1991. A generator at another AT&T switching station in Manhattan fails, and backup battery power is exhausted before operators notice the problem. Phone service into and out of New York City is halted. The failure paralyzes air traffic control systems, leading to flight delays and cancellations up and down the East Coast. The Federal Aviation Administration later awards a $558 million contract for new inter-airport communications links to MCI.[3]

- March 25, 1992. Just before the close of trading on the New York Stock exchange, a clerk at Salomon Brothers mistakenly instructs the company's computers to sell 11 million shares, rather than $11 million worth, of a certain stock. Propagated instantly to computers around the world, the $500 million sale triggers a frenzy of other sell orders. The Dow Jones' resulting free fall -- 15 points in five minutes -- is halted only by the closing bell.[4]

- September 22, 1993. A barge adrift in an Alabama bayou collides with a railroad trestle, severing its rails. Circuitry designed to detect a break in the tracks fails to trigger stop signals. Minutes later, an Amtrak train plunges off the bridge into 30 feet of water, killing 47 passengers.[5]

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[2] Ibid., 73-108.

[3] Edmund L. Andrews, "A.T.&T. Employees Missed Breakdown," *The New York Times* (Sep. 19, 1991) A1, D21; Edmund L. Andrews, "MCI Wins Contract for Air-Control Link," *The New York Times* (March 18, 1992) D4.

[4] Casey, 109-116.

[5] Ronald Smothers, "Dozens Are Killed in Wreck of Train in Alabama Bayou: Amtrak's Worst Accident," *The New York Times* (Sep. 23, 1993) A1, D21.

Mishaps like these never fail to evoke surprise and consternation. One major task of any technology-related organization, after all, is to catch small errors while they are still small. Yet in each of these cases, an innocent and seemingly detectable irregularity -- a misleading altitude reading, a broken switch, a typographical error -- triggered unanticipated, automatic, and quite disastrous behaviors in the larger system. Breakdowns in complex systems are among the most provocative of technological catastrophes, because they force citizens to question the rightness of modern society's strategies for controlling critical or hazardous technologies.

Consider the following list of failures that contributed to a recent technological disaster: The plant's control room was laid out with little attention to ergonomic efficiency. Control room instruments failed to measure important system variables. Sometimes the instruments registered incorrect data. The controls themselves were designed in a way that did not prevent operators from implementing catastrophic combinations of actions. During operator training, emergency drills failed to simulate realistic failure conditions. The plant's operators were unfamiliar with some of the basic physical principles underlying the production system. Once the actual malfunction began, the operators interpreted the situation incorrectly. Believing they had no choice, they interfered with automatic emergency systems in ways forbidden by plant guidelines. They overlooked several available indications that total failure was imminent. Undetected mechanical malfunctions added to the confusion. With supervisors looking on, finally, the operators took steps that made catastrophic failure irreversible.

To which disaster does this description apply? *In fact, these failures are frighteningly generic.* They occurred during the Three Mile Island accident and were repeated at Bhopal and Chernobyl. The operators, the instruments, and the chronologies of these disasters are in a sense interchangeable, since the same basic inadequacies in contemporary modes of technological control were at work in each case. Each new disaster underscores the synergy of human fallibility and imperfect engineering. It is not artistic license, then, when the drama in disaster films like *Dr. Strangelove, The China Syndrome,* or *WarGames* takes place inside a control center of some kind. Recent history shows that control rooms are precisely where large technological systems go *out of control.*

The idea that humans can transform the natural environment through their mastery of machines dates back to the Enlightenment -- as does the notion that the well-ordered society operates according to mechanical principles. ("By art is created that great LEVIATHAN, called a COMMONWEALTH, or STATE, which is but an artificial man," Thomas Hobbes wrote in 1651.[6]) In this century the control room, with its gauges, buttons, flashing lights, and computer screens monitored by attentive, clean-cut technicians, has become a universal icon of the advanced industrial state. The aura of technological prowess emanating from "mission control" during the days of NASA's Apollo moon missions highlighted the defining ideology of technological society: Control is Power.[7]

But this power can slip away with remarkable ease. The disasters I investigate in the following chapters occurred in large, fixed technological systems where the use of highly energetic processes or highly toxic substances (or both) required strict safety procedures and automated control mechanisms. In each case, human errors, mechanical malfunctions, and unnoticed design flaws combined to defeat these safeguards and bring on catastrophe, raising fundamental questions in the minds of both experts and lay citizens about the reliability and desirability of the systems themselves.

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[6] Thomas Hobbes, *Leviathan,* Michael Oakeshott, ed. (New York: Collier, 1962).

[7] On the U.S. space program's role as jingoistic "technological display," see Michael Smith, "Selling the Moon," in Richard W. Fox and T.J. Jackson Lears, eds., *The Culture of Consumption* (New York: Random House, 1986).

I had no such criteria in mind when I chose to study these particular episodes. I had intended only to single out the most memorable disasters of recent decades, with an eye toward discovering whether and why each had generated a political response among the citizenry. But it gradually became clear that the New York City blackouts, the Bhopal gas leak, and the Three Mile Island and Chernobyl meltdowns -- aside from being memorable, close together in time, and richly documented -- also shared parallel histories that seemed to define the limits of the quest for total control over large-scale technological systems. Most importantly, there was *no one in charge* of these systems when crisis hit -- or more precisely, the people, procedures, and backup devices supposedly in place to prevent catastrophe proved unexpectedly ineffective or inoperative. Control collapsed on both the technical and organizational levels, inviting criticism from those who depended on these systems and their safe operation. What had drawn me to these case studies, I realized, was the suspicion that *technological control is itself a political phenomenon,* in the sense that it involves decisions about the way people live and the hazards they must bear, and that control breakdowns are therefore moments of political instability and potential social and technological change.[8]

A clearer understanding of the politics of control breakdowns in large-scale systems can help identify the forces straining traditional modes of citizenship, and may even point out opportunities for the expansion of citizens' roles in future decisions about technology -- leading, perhaps, to a more democratic technological order in the future. In this chapter, I will flesh out some of the terms of my argument, with the goal of providing a framework or "experimental method" for thinking about the upcoming case studies. Large technological systems, complexity, cybernetic control, and the political significance of control breakdowns will each be dealt with in turn. I will begin, however, by drawing some necessary distinctions between control breakdowns in complex, large-scale technological systems and other kinds of catastrophes.

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[8] Smaller or less complex technologies can also fail catastrophically (as in an oil tanker accident or a dam break, for example), but these kinds of disasters do not seem to me to raise the same issues of control and its distribution, and so may have different meanings from a cultural or political standpoint.

Why Large-Scale System Disasters?

The broadest, most inclusive definition of "disaster" might be *an unexpected, extraordinary event that commences suddenly and disrupts the routines of human life in undesirable ways.* Because disasters place people, organizations, and societies under unusual stresses, they can often be sources of psychological, sociological, and political insight. This is why disasters have been a staple of social commentary for millennia, from Pliny the Younger's account of the destruction of Pompeii in 79 A.D. to Voltaire's history of the 1755 earthquake in Lisbon, and why "disaster research" has recently acquired scholarly respectability, winning both government funding and a place in the academy.[9] But different kinds of disasters have very different stories to tell.

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[9] The first disaster of any kind to receive systematic attention from sociologists was a technological one: the accidental explosion of a munitions ship in Halifax Harbor, Nova Scotia, that killed 2,000 people and leveled two square miles of the city on December 6, 1917 (S. Prince, *Catastrophe and Social Change* , New York: Columbia University Press, 1920). Since then, however, the bulk of the scholarly work on disasters has focused on natural catastrophes (see Drabek, *Human System Responses to Disaster*). This is unsurprising, since

In the following pages I will focus on catastrophic control failures in large, complex technological systems, and before arguing that these failures have special political significance it will help to show how they fit into the general bestiary of catastrophes.

Because the immediate *effects* of disasters are often similar -- death, injury, disease, social and psychological trauma, and environmental destruction -- they are probably best classified according to their *origins* and *mechanisms*. The most commonly used distinction is that between disasters originating in the natural environment and those arising from the activities of humans. The boundary between "natural" and "technological" disasters can, admittedly, be arbitrary and hard to discern; as Rosalind Williams, the cultural historian, has pointed out, "Technological systems always include people and nature, and natural ones include people and technology."[10] Devastating flooding in the Mississippi River Valley in 1993, for example, resulted both from both the "natural" fact of unusually heavy rainfall and from the "technological" fact that the river, squeezed into an artificially narrow channel by hundreds of miles of man-made levees and dams, rapidly

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deaths and other social costs from fires, floods, earthquakes, storms and the like have always far exceeded those from purely technological causes. Knowing how individuals and groups respond in these crises can help emergency management agencies, international relief organizations, and civil defense organizations plan for wars and other future disasters; as a result, social and psychological responses to disaster are far better understood than political reactions. Even with today's heightened awareness of technological threats to health and environmental integrity most studies of human responses to hazards continue to concentrate on people's "cognitive and/or behavioral adjustments" to these problems. (See, for example, Valerie Preston, S. Martin Taylor, and David C. Hodge, "Adjustment to Natural and Technological Hazard," *Environment and Behavior* (March, 1983) 143-64; Charles B. Wilkinson, "Aftermath of a Disaster: The Collapse of the Hyatt Regency Hotel Skywalks," *American Journal of Psychiatry* (Sep., 1983) 1134-39; Julian Barling, Stephen D. Bluen, and Rolene Fain, "Psychological Functioning Following an Acute Disaster," *Journal of Applied Psychology* (72: 1987) 683-90; Robert J. Ursano and Carol S. Fullerton, "Cognitive and Behavior Responses to Trauma," *Journal of Applied Social Psychology* (20: 1990) 1766-75.)

[10] Personal communication, June 8, 1994.

overtopped and destroyed these very control structures.[11] The damage caused by natural disasters, moreover, is often magnified by, or even wholly attributable to, technological factors; the 1994 Northridge earthquake in Los Angeles was significant because it demonstrated the structural integrity (or lack thereof) of the city's buildings and highways. But the distinction between natural and technological disasters may be worth preserving nonetheless, if only because historians and social scientists have discovered that the questions of *responsibility* raised by disasters perceived as predominantly technological in origin are much more problematic than those surrounding disasters seen primarily as "acts of God."[12]

The difference is partly captured by the story of the Buffalo Creek flood of 1972, caused by the collapse of a makeshift coal-slag dam built by the Pittston Corporation across a West Virginia coal mining valley. It had been raining steadily the night before the dam broke. Just before 8:00 a.m. on February 26, the slag became saturated, turned to something like Jell-O, and collapsed on itself, releasing 132 million gallons of thick black water into the valley below. Within minutes 125 valley residents were swept to their deaths by the thundering wall of water. Hundreds more escaped to the hills barely in time, only to watch their family members, friends, houses and vehicles carried away like toys. Afterward it was as if the old mining-camp towns along Buffalo Creek had never existed. Every tree, every house, every telephone pole and street sign had been scoured from the landscape.

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[11] *New York Times* reporter Keith Schneider wrote: "Two assessments by the Army Corps of Engineers, one completed almost a decade ago and one done this week for the *New York Times*, found that flood crests in Iowa, Illinois and Missouri would have been two to three feet lower had the river not been confined by hundreds of miles of levees on both sides of the Mississippi." Schneider, "Like Flood, New Policy Could Inundate Levees," *The New York Times* (July 18, 1993) 23.

[12] See, for example, Roger E. Kasperson and K. David Pijawka, "Societal Response to Hazards and Major Hazard Events: Comparing Natural and Technological Hazards," *Public Administration Review* (Special Issue, "A Challenge for Public Administration," 1985) 7-18. Kasperson and Pijawka write: "Technological hazards pose different, and often more difficult, management problems than do natural hazards. Contributing factors to this greater difficulty are...the broader opportunities for control intervention; the perceived amenability of technological hazards to fixes; and the simultaneous need to enlarge benefits and reduce risks in judging the tolerability of technological hazards and instituting control strategies" (17).

Kai Erikson's visit to Buffalo Creek shortly after the disaster turned up evidence of social and cultural damage almost worse than the flood's physical effects. The sociologist traveled to the scene as a consultant to the Washington law firm that represented some 650 of the survivors in a suit against Pittston. The psychic scars borne by the survivors, he found, were far worse than one might have observed in an area struck by a tornado, hurricane, or some other natural event. The people of Buffalo Creek were suffering not simply from the loss of their loved ones and all their material belongings, but also from a deep blow to their trust in Pittston and the other social institutions that they had supposed were there to take care of them. Erikson's findings helped to define and legitimate this kind of victimization, winning the plaintiffs an unprecedented $13.5 million settlement.[13]

Events at Love Canal, New York, provided further evidence of technological victimization. After experiencing years of mysterious illnesses and unpleasant odors, residents of the Niagara Falls neighborhood learned between 1976 and 1978 that their homes had been built on the edge of a long-forgotten industrial waste dump containing high levels of toxic chemicals. Press accounts led to national attention and state and federal investigations, which confirmed a high incidence of miscarriages in the area. Prodded by local activists, the federal government eventually bought up most of the land in Love Canal and relocated its families. But relocation was by no means a total solution to the crisis. The insidious nature of the toxic threat has caused ongoing uncertainty and stress, in addition to painful social stigmatization, for many former Love Canal homeowners. The disaster inspired one former Love Canal resident and local leader, Lois Gibbs, to establish what is now one of the nation's most active grassroots environmental organizations, the Citizens' Clearinghouse for Hazardous Waste.

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[13] See Kai T. Erikson, *Everything In Its Path: The Destruction of Community in the Buffalo Creek Flood* (New York: Simon & Schuster, 1976).

Erikson comments: "The people who have gone through these experiences are suffering forms of trauma that have not been talked about enough. What makes something like Love Canal so hard to bear, aside from the damage it does, is first of all that other human beings did it, as often as not without expressing any sorrow for having done it. But in addition, toxicity itself has the character that it contaminates the world in which you live in such a way that the disaster never really ends. You have this feeling that toxic materials have worked their way into the grain of the world and into the tissues of your body, and even into your children's bodies."[14]

The feelings of personal violation engendered by technological accidents can linger for decades. As a consequence, technological disasters often lack discrete endings analogous to rebuilding after a natural disaster. Even fourteen years after the Buffalo Creek flood, psychiatrists found residents who had participated in the suit against Pittston to be suffering from high rates of anxiety, depression, belligerence, alcoholism, and family strife.[15] "With a natural disaster the start and finish are both very well-defined, and the result is to restore a social normalcy," says William Freudenburg, a sociologist who has studied differing perceptions of technological hazards among lay and technical communities. But with many technological disasters, Freudenburg says, "rather than the restoration of normalcy, you have the end of normalcy."[16]

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[14] Telephone interview, Nov. 11, 1992

[15] Jack Zusman and Jesse Simon, "Differences in Repeated Psychiatric Examinations of Litigants to a Lawsuit," *American Journal of Psychiatry* (Oct. 1983) 1300-04; Bonnie L. Green, et al., "Buffalo Creek Survivors in the Second Decade: Comparison with Unexposed and Nonlitigant Groups," *Journal of Applied Social Psychology* (20: 1990) 1033-50.

Natural disasters have some of the same power as technological disasters to reveal hidden pathologies in human affairs. Huge forest fires in the western United States in 1988, for example, proved that the U.S. Forest Service's longstanding policy of suppressing natural fires had merely increased the load of combustible material, inviting an uncontrollable conflagration.[17] The Mississippi flooding of 1993 showed that the Army Corps of Engineers' long campaign to restrict the river to a narrow channel had exactly the opposite effect, and as a result this policy may soon be reversed.[18]

While natural disasters can demonstrate the futility of attempts to control nature, however, technological disasters are better at revealing the weaknesses and inequities of the systems structuring social life. Both natural and technological disasters are sudden and powerful, but only technological disasters are seen as preventable. When a piece of technology breaks down catastrophically, people ask *how* and *by whom* the failure should have been prevented and whether control and danger are being shared fairly or democratically -- political questions, all. Since life in the industrialized world depends on a growing network of sophisticated technologies, failures striking these technologies demand particular attention from observers interested in the relationship between technology and citizenship.

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[16] Telephone interview with the author, Nov. 3, 1992.

[17] Stephen J. Pyne warned of this problem in *Fire in America: A Cultural History of Wildland and Rural Fire* (Princeton, N.J.: Princeton University Press, 1982).

[18] On the Army Corps' long battle against the Mississsippi, see John McPhee, *The Control of Nature* (New York: Farrar, Strauss, and Giroux, 1989) 3-94. See also Schneider, "Like Flood, New Policy Could Inundate Levees," and Isabel Wilkerson, "Running Wild: The Mississippi Reclaims its True Domain," *The New York Times* (July 18, 1993) IV: 1, 3.

Just as natural disasters can be classified according to whether they are geological, celestial, climatological, or biological in origin, technological disasters stem from a variety of identifiable causes (see Figure 1.1). As we hone in on the type of disaster central to this study, it is important, first, to distinguish between *deliberate* and *accidental* technological catastrophes. War, genocide, crime, sabotage, terrorism and other examples of man's inhumanity to man are often carried out through technological means, and all are disastrous for various social groups. Robert Jay Lifton and others, for example, have documented the ongoing psychic and social disruption caused by one of the twentieth century's most infamous man-made catastrophes, the bombing of Hiroshima.[19] Such disasters remind us of the unimaginable destructiveness of modern technologies of war, and of the fact that our control over these state-organized technologies is extremely remote: decisions about whether to build, deploy, and use devices such as nuclear weapons can only be made under conditions of great secrecy. Just as important, the memory of disasters like Hiroshima underscores the fact that the technological hazards imposed by modern industrialism are now global in scope. No one is safe from the threat of nuclear conflict.

It is important to note, however, that what we fear most about nuclear weapons, terrorist bombs, computer viruses, and the like is that *they will work exactly as they were designed to do.* Human ingenuity has created these technologies -- the "genie has been let out of the bottle" -- and the challenge now is to prevent their use.[20] This is a very different social problem from the threat of accidental catastrophes, which arise from the sudden and unexpected *misbehavior* of technologies we use every day. Accidental breakdowns lead us to question whether the operations of important technologies and technological systems are defined by well-understood rules -- as we are repeatedly told by these systems' managers, and as we would like to believe -- or rather, whether social commitments and decisions about many of these technologies have been made on the basis of a misleading and incomplete portrayal of their internal characteristics (especially the relationship between idealized "rules" and actual practices).[21] Deliberate catastrophes merely confirm our knowledge that technology can be put to destructive ends. Accidental disasters, on the other hand, require people to form a more sophisticated understanding of technologies that exist for putatively constructive purposes -- a fact with direct bearing on changing conceptions of citizenship.

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[19] See Robert Jay Lifton, *Death in Life: The Survivors of Hiroshima* (New York: Random House, 1967); John Hersey, *Hiroshima* (New York: Alfred A. Knopf, 1946, new edition: 1985).

One way to subdivide the large class of accidental technological disasters into smaller classes is to ask what kinds of entities can initiate these events. *Individuals* operating technological devices in unintended ways can provoke numerous varieties of small disasters, including accidents at home, at work, and on the roads. Ignorance, negligence, and miscalculation are often at the root of such accidents, so the victims have no one to blame but themselves or other reckless individuals. *Objects* standing alone can also fail

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[20] To be sure, the possibility exists that an *accidental* nuclear war could be triggered through a series of breakdowns in control, communications, and intelligence. This would be the ultimate accidental technological catastrophe, but preventing it is, in a sense, the entire mission of organizations like NORAD and SAC. It falls to politicans and diplomats to prevent the failure of the theory of deterrence, that is, the *deliberate* use of nuclear weapons.

[21] Brian Wynne explores this possibility at length in "Unruly Technology: Practical Rules, Impractical Discourses and Public Understanding," *Social Studies of Science* (Vol. 18, 1988) 147-67.

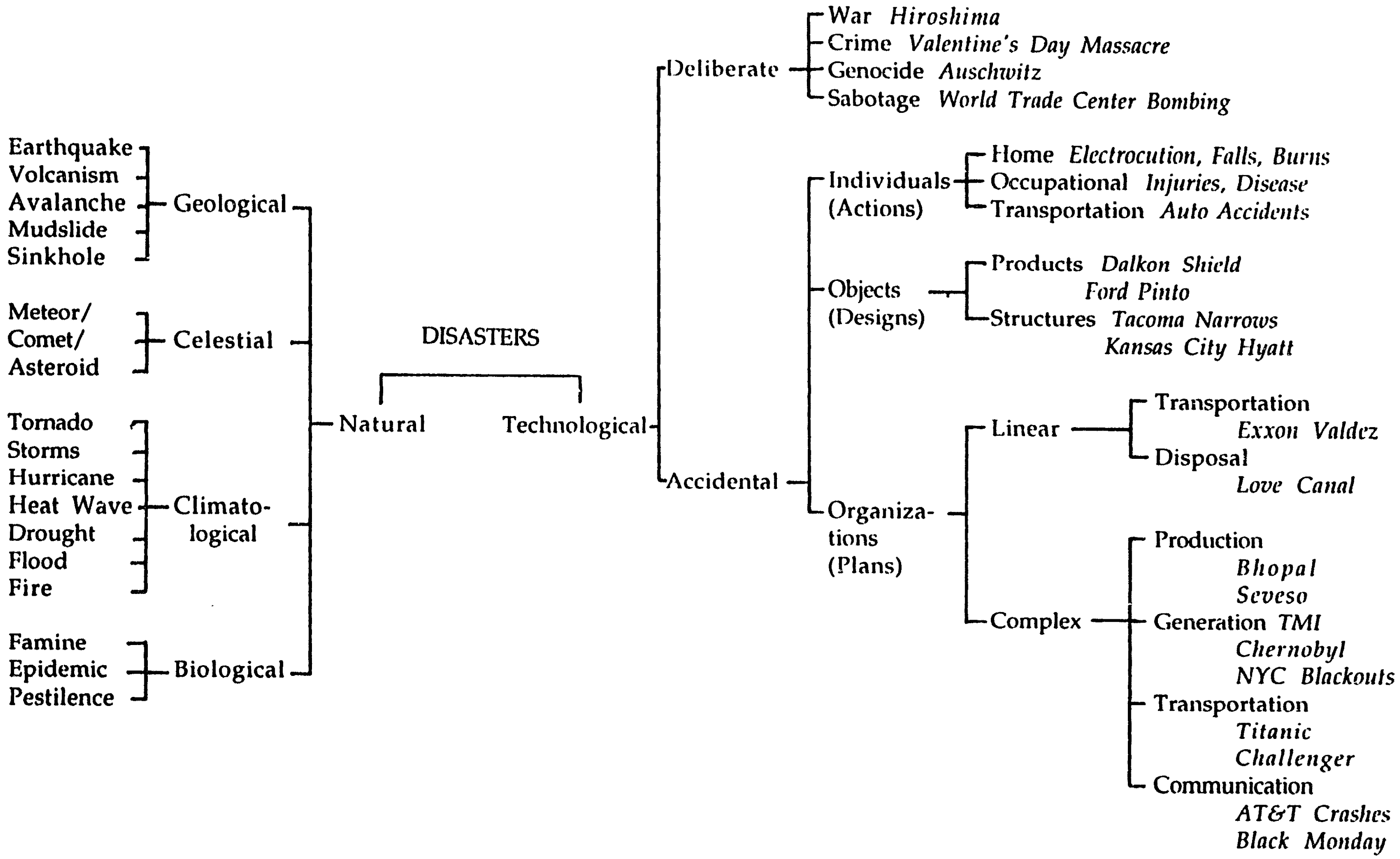
DISASTERS
Natural
Technological
Earthquake
Volcanism
Avalanche
Mudslide
Sinkhole
Geological
Meteor/
Comet/
Asteroid
Celestial
Tornado
Storms
Hurricane
Heat Wave
Drought
Flood
Fire
Climato-
logical
Famine
Epidemic
Pestilence
Biological
Deliberate
War *Hiroshima*
Crime *Valentine's Day Massacre*
Genocide *Auschwitz*
Sabotage *World Trade Center Bombing*
Accidental
Individuals
(Actions)
Home *Electrocution, Falls, Burns*
Occupational *Injuries, Disease*
Transportation *Auto Accidents*
Objects
(Designs)
Products *Dalkon Shield*
Ford Pinto
Structures *Tacoma Narrows*
Kansas City Hyatt
Organiza-
tions
(Plans)
Linear
Transportation
Exxon Valdez
Disposal
Love Canal
Complex
Production
Bhopal
Seveso
Generation *TMI*
Chernobyl
NYC Blackouts
Transportation
Titanic
Challenger
Communication
AT&T Crashes
Black Monday

FIGURE 1.1: A Taxonomy of Disasters, drawing on concepts and case studies in history, sociology, and engineering. Compiled by the author.

catastrophically, usually as the result of careless design or bad choices of materials and construction methods. Product failures like the exploding Ford Pintos of the early nineteen-seventies fall into this category, as do structural failures like the Buffalo Creek disaster and the collapse of the Kansas City Hyatt Hotel walkways in 1981. Recovery from this kind of failure usually proceeds according to well-established tort procedures and engineering practices. The courts attempt to pinpoint the origin of the failure, often negligence of some kind; the parties found responsible are forced to compensate the victims or their survivors; and engineers, perhaps under the pressure of new regulations or public demands for safety reforms, go on to build a better object. Citizen intervention in such cases takes the form of litigation or movements for "consumer rights" -- by which is usually meant the right to full information about a product or the right to compensation for its defects, not the right to be involved in its design or placement.

Accidental technological disasters initiated by a third kind of entity, *organizations*, lead to a different set of political possibilities. Organizations include individuals and technological objects, but combine them with a new element: planning. Just as technological devices are defined by their designs, organizations exist to carry out plans. (The authority to make plans and oversee their execution is one way of defining control, a theme to which we will return shortly.) The breakdown of an organized technological process simultaneously calls into question the competence of the people belonging to the organization, the adequacy of the technological designs which the organization exists to exploit, and the wisdom of the original plan of operation. Forced to defend itself on these three fronts, an organization suffering a disaster may become vulnerable to external pressures for change, and it is at this moment that citizens may throw off their status as the passive "victims" of technological failure and win some measure of control over the technology's design, operation, and planning.

The plans technological organizations carry out may be either *complex* or *linear* in nature. These terms will be explained in the next section; suffice it to say for now that complex technological processes are more prone to catastrophic organizational breakdowns than linear ones. The basic purpose of any complex technological organization, finally, is either *to make* or *to move*. If it makes things, it is in *production*; if it makes energy, it is in *generation*; if it moves people or things, it is in *transportation*; and if it moves information, it is in *communication*.

The domain of this study, then, is the lower right-hand corner of the branching chart in Figure 1.1: complex, organizational, accidental technological disasters. The four case studies are in the areas of energy generation and manufacturing, but examples of large-system breakdowns are available in the fields of transportation and communication as well. To limit the study's field of vision to this single variety of catastrophe is not to deny that other kinds may have equal meaning for modern societies, but it is a way of asserting that the connection between complex organizational breakdowns and ideas of citizenship and democracy has, to date, been left largely uncharted.

Large Systems, Complexity, and the Limits of Cybernetic Control

It is common to speak of networks of artificial devices or structures as systems, as in the telephone system, the interstate highway system, or data processing systems. But since these networks cannot function apart from their human planners and operators, it seems justifiable to expand the meaning of "system" to incorporate people and organizations. This is just what some historians and social researchers have done -- perhaps too enthusiastically. The catch-all terms "large technological system," "large-scale sociotechnical system," "megatechnical system," and the like are used today to refer to entities so varied and widespread that it is difficult to say anything precise about them, except that their dominance is what defines modern technological societies.

Born of the nineteenth century but fully realized only during the twentieth, large technological systems are amalgams of specialized hardware and specially-skilled people organized bureaucratically for the efficient and profitable exploitation of technological processes. One can hardly move through a day's activities without encountering at least a dozen of them, including telephones, television, computers and computer networks, roads and highways, air and rail transportation, and systems for the distribution of water, electrical power, gasoline, and food and the collection of garbage and wastewater. Manufacturing or generating complexes like petroleum refineries, chemical process plants, and nuclear power stations count as large technological systems, though they are also components in even larger systems. To use a description offered by Langdon Winner, large technological systems are marked by "large size, concentration, extension, and the complex interconnection of a great number of artificial and human parts." The result of this interconnection, Winner observes, is "a quantum jump over the power and performance capabilities of smaller, more segmental systems. In this regard, the genius of the twentieth century consists in the final connecting of technological elements taken from centuries of discovery and invention."[22] Led by historian of technology Thomas P. Hughes, scholars in science and technology studies have developed a growing interest in recent years in the genesis and expansion of large technological systems,[23] but few have yet examined how these systems evolve in response to catastrophic failure.

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[22] Langdon Winner, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (Cambridge, Mass.: MIT Press, 1977) 238.

Without speaking of large technological systems *as* systems it would be hard to describe the structural and behavioral features that contribute to failure, and this is the real reason to use the term here. When large technological systems break down it is almost never due to a single cause like a burned-out fuse or an operator's mistaken command. Simple lapses like these are interdicted before they can cause a chain of other problems; that is what safety devices are for. Truly catastrophic breakdowns only occur as the result of *unexpected interactions between multiple smaller failures.*

This is the central insight in Charles Perrow's work on system accidents. Two kinds of interactions can take place within a technological process, Perrow explains: "linear" interactions, between components that immediately follow each other in a planned sequence of production, and "complex" interactions, between one or more components outside the normal production process, whether by design or not. The larger the number of complex interactions that can take place within a large technological system, the more vulnerable it is to a system accident.[24] The 1991 AT&T generator failure that left airline passengers stranded from Boston to Washington was a perfect example of a system breakdown caused by complex interactions between supposedly unrelated components of a large technological system.

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[23] See especially Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983); Wiebe E. Bijker and Thomas P. Hughes, eds., *The Social Construction of Technological Systems* (Cambridge, Mass.: MIT Press, 1987); Thomas P. Hughes and R. Mayntz, eds., *The Development of Large Scale Technical Systems* (Boulder, Colo.: Westview Press, 1988); North Atlantic Treaty Organization Advanced Research Workshop on Social Responses to Large Technical Systems: Regulation, Management, or Anticipation, *Social Responses to Large Technical Systems: Control or Adaptation,* Todd LaPorte, ed. (Dordrecht: Kluwer Academic Publishers, 1991).

[24] Perrow, *Normal Accidents,* 77-78.

System complexity -- the extent to which a system permits complex interactions -- is, in itself, no index of undesirability. We happily rely on any number of complex technological systems to protect us from danger, from the computerized anti-lock brakes that help us steer out of skids to the weather satellites that warn of us approaching hurricanes. And as Perrow points out, "complex systems are more efficient than linear systems...There is less slack, less underutilized space, less tolerance of low-quality performance, and more multifunction components."[25] What determines a system's hazardousness is not just the degree of its complexity but also whether its human operators are able to keep pace with that complexity by identifying hidden interactions before they cause trouble. As Winner notes, "Complexity looms as a distinctive problem when systems of interconnected parts begin to tax the human ability to make the artificial whole intelligible...In almost no instance can artificial-rational systems be built and left alone. They require continued attention, rebuilding, and repair. Eternal vigilance is the price of artificial complexity."[26]

Nor is complexity the sole ingredient of a system accident. It is usually possible to stop unexpected interactions from multiplying catastrophically *unless* the system is also "tightly coupled" -- an engineering term meaning that there is little slack or buffer in a chain of causation. In tightly coupled systems, including chemical plants, spacecraft, nuclear reactor cooling systems, electrical power grids, and passenger jets, individual decisions produce quick results, with little time for recovery if a decision turns out to have been flawed. "Loosely coupled systems...can incorporate shocks and failures and pressures for change without destabilization," Perrow writes. "Tightly coupled systems will respond more quickly to these perturbations, but the response may be disastrous."[27]

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[25] *Normal Accidents,* 88.

[26] Winner, *Autonomous Technology* , 183.

An example of a disaster involving very tight coupling (but in which the "system" itself was defined only loosely) was the crash of a two-passenger helicopter on an elevated highway approaching the New Jersey side of the Lincoln Tunnel on May 6, 1994. The helicopter, flying at an altitude of only 150 feet, clipped and severed a non-energized wire on an overhead power line. The copter crashed onto Interstate 495, killing both of its occupants and spilling fuel onto a commuter parking lot below. The severed wire, meanwhile, brushed against an electrified line and was itself energized; it scattered sparks over the parking lot, igniting the spilled fuel and incinerating 78 vehicles. The downed power line cut off electricity to 25,000 homes, and highway shutdowns caused hours of gridlock throughout northern New Jersey and Manhattan.[28] At no point in this bizarre sequence of events was there time for anyone to intervene. The disaster resulted from the sheer physical concentration of the urban environment, manifested when helicopter, power line, highway, parking lot, and fuel all occupied the same space at the same time: the tightest coupling possible.

When a system is both complex *and* tightly coupled, the stage is set for what Perrow called a "normal accident": an "odd term...meant to signal that, given the system characteristics, multiple and unexpected interactions of failures are inevitable."[29] The meltdown at Three Mile Island was Perrow's paradigmatic "normal accident." Among the other technologies whose complexity and tight coupling invite special scrutiny are -- not surprisingly -- electrical grids and chemical manufacturing. These technologies are not new, of course, and the phenomena of complexity and tight coupling have been known to engineers under one name or another for generations. The technique that has been developed to deal with them is called cybernetic control.

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[27] *Normal Accidents*, 92.

[28] Robert D. McFadden, "2 Die as Helicopter Crashes Near Lincoln Tunnel," *The New York Times* (May 6 ,1994) A1, B4; Iver Peterson, "Faster Licensing Path Lured Helicopter Occupants to U.S.," *The New York Times* (May 7 ,1994) 25, 28.

Control has always been a crucial function of large industrial organizations. The great railroads of the American continent devised the first systematic methods for ensuring smooth operations through the prevention of delays and collisions, and the form of corporate organization that evolved alongside these methods permanently altered the way Americans do business.[30] Frederick W. Taylor and Henry Ford systematized the control of mass production early in the twentieth century through their techniques of "scientific management" and vertically integrated assembly-line manufacturing. Control over man-machine systems emerged as a scientific preoccupation during World War II, when reliable methods were needed for such tasks as aiming anti-aircraft guns against rapidly moving targets. Research on automatic control by MIT researcher Norbert Wiener and others in the late nineteen-forties led eventually to the design of robots and electronic controls for almost every conceivable industrial task, including the operation of nuclear power stations and continuous-process plants like chemical factories and petroleum refineries.

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[29] *Normal Accidents*, 5.

[30] See Alfred Chandler, *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, Mass.: Belknap Press, 1977).

The foundation of cybernetics was Wiener's insight that electro-mechanical systems employing "feedback control" could take over human tasks like computation and forecasting and perform them with much greater speed and accuracy. Feedback, crudely defined, is information about the difference between the actual outcome and the desired outcome of a step in a continuous control process; this information is "fed back" into the process so that on the next step the real outcome may be brought closer to the desired one.[31] Many human neuromuscular feats, from picking up a pencil to driving a car, are accomplished through a kind of unconscious feedback, so the variety of operations that can be usurped by automatic control systems is, in principle, very large.[32] Indeed, Wiener described cybernetic control in explicitly physiological terms: "The many automata of the present age are coupled to the outside world for both the reception of impressions and for the performance of actions. They contain sense organs, effectors, and the equivalent of a nervous system to integrate the transfer of information from one to the other...It is scarcely a miracle that they can be subsumed under one theory with the mechanisms of physiology."[33]

That cybernetic theory and high-speed computers developed alongside one another was no accident. Wiener's original work on control and communication at MIT was inspired by Vannevar Bush's success with the Differential Analyzer, an early computer for the solution of single-variable differential equations. Wiener wrote in 1948, "It has long been clear to me that the modern ultra-rapid computing machine was in principle an ideal central nervous system to an apparatus for automatic control; and that its input and output need not be in the form of numbers or diagrams but might very well be, respectively, the readings of artifical sense organs, such as photoelectric cells or thermometers, and the performance of motors or solenoids."[34]

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[31] See Norbert Wiener, *Cybernetics, Or Control and Communication in the Animal and the Machine* (Cambridge, Mass.: The MIT Press, 1948, 1961) 6-7.

[32] Engineer Thomas Sheridan writes that "humans are multi-dimensional feedback control systems, continually moving off-track and correcting themselves in a progression of feedback loops encompassing thoughts, whole-body movements, manipulation of controls and system feedback." *Telerobotics, Automation, and Human Supervisory Control* (Cambridge, Mass.: MIT Press, 1992) 316,

[33] Wiener, Cybernetics, 43.

As computers grew in speed and sophistication during the nineteen-fifties, Wiener's dream began to take on reality. Computers became part of the control loop in many cybernetic systems, performing such tasks as augmenting and stabilizing aircraft control, filtering signal patterns from background noise, and generating electronic displays.[35] These techniques greatly increased the flexibility and reach of man-machine systems, making it possible for human supervisors to monitor and occasionally intervene in feedback control processes while leaving much of the "dirty work" to machines. Technological systems could now be built to operate in environments that would previously have been considered too hazardous for human activity: the ocean bottom, outer space, the interiors of nuclear reactors.

This increase in risk-taking with improved technology is similar to an effect among consumers that economists call "offsetting behavior." A recent study by the Highway Loss Data Institute, an insurance industry research group, provides an example of this pattern. Institute researchers who tallied insurance claims were surprised to find that antilock braking systems have *not* helped to further the 50-year trend in the U.S. toward lower death rates per mile traveled by automobile. Economist Robert S. Chirinko speculates,

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[34] Ibid., 26.

[35] See Sheridan, *Telerobotics, Automation, and Human Supervisory Control* , 7-12.

"When a new technology arrives, drivers will alter their behavior. They will realize that cars with antilock brakes are safer, which means the cost of risky driving is lower. Many of them will drive more aggressively, or drive more often in dangerous, inclement weather. Thus, even if accidents are less serious because these brakes do control skidding, the number of potential accident situations will increase."[36]

The computerization of cybernetic control systems, as we will discover, has made room for offsetting behavior on a gargantuan scale. The radar-evading "flying wing" design of the Northrop Corporation's B-2 bomber, for example, is so aerodynamically unstable that only a computer can control its flight. Nuclear energy, to take another obvious case, poses safety challenges that would be impossible to meet without automated controls. The essence of a nuclear reactor is to bring together enough uranium and moderating substances so that spontaneous fission events can build into a heat-generating chain reaction. Assuring that there are *always* enough cooling and control substances present to draw off the excess heat and stop the reaction when necessary is an extremely tricky process, one nuclear engineers are still attempting to perfect after four decades of research. In an American-style nuclear reactor, there is no choice but to automate the backup systems needed to ensure that a loss of coolant does not lead to a worst-case failure (that is, a meltdown), and as a result these plants have become tangles of plumbing and electronics so complex that not even their operators understand them fully, as we will see in Chapter 3. Choosing to build a large number of nuclear power plants in the belief that safety systems will work in an emergency is not so different, then, from choosing to drive cars more aggressively in the belief that their sophisticated brakes will prevent serious accidents. Both beliefs may be justified, but the number of potential accident situations will multiply.

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[36] Robert Chirinko, "As Cars Get Safer, Drivers Take Risks," *The New York Times* (April 10, 1994) III: 17.

The analogy between computers and cars is historically apt, since Wiener coined the word "cybernetics" from the Greek *cybernetes*, meaning driver, steersman, or pilot. ("Governor" and hence "government" derive from a Latin corruption of the same word.) From the earliest stages of research on cybernetics, it was obvious what kinds of advances the combination of computers and control would make possible, and Wiener was the first to worry about how his work would be applied:

> We have contributed to the initiation of a new science which embraces technical developments with great possibilities for good and evil. We can only hand it over into the world that exists about us, and this is the world of Belsen and Hiroshima. We do not even have the choice of suppressing these new technological developments. They belong to the age...The best we can do is to see that a large public understands the trend and bearing of the present work, and to confine our personal efforts to those fields, such as physiology and pyschology, most remote from war and exploitation...There are those who hope that the good of a better understanding of man and society which is offered by this new field of work may anticipate and outweigh the incidental contribution we are making to the concentration of power (which is always concentrated, by its very conditions of existence, in the hands of the most unscrupulous). I write in 1947, and I am compelled to say that it is a very slight hope.[37]

Wiener's main fear, it seems, was that cybernetics would form the basis of a new generation of more dehumanizing technologies for industrial production and more lethal technologies for war, and in this he was absolutely correct. But Wiener was also acknowledging the paradoxical reality that the new science of control *could not itself be controlled* -- "We do not even have the choice of suppressing these new technological developments." Cybernetics could serve wise or foolish ends with equal efficiency, and it might be used in ways that would make human existence not simply easier but also more dangerous.[38]

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[37] Wiener, *Cybernetics*, 28-29.

Control rooms at complex facilities like nuclear plants and chemical factories have indeed become nodes of power in technological societies, places where decisions affecting the comfort and safety of millions are made every day. But as Perrow's work has shown, systems complex enough to require control rooms are *inherently vulnerable* to unanticipated failures; after this level of complexity has been reached, the addition of safety features may make the system *more* vulnerable, not less. No matter how well-behaved are the system's technical components, moreover, the ever-present possibility of human error places its own limit on system reliability.

Engineers in the field of "human supervisory control" have attempted to minimize the threat from human error by building industrial control systems with greater and greater autonomy. This project suffers, however, from the fundamental flaw that (as industrial psychologist James Reason has written) it "was not conceived with humans in mind." It arose instead from the microchip revolution, military demands, the feasibility of assigning ever-more-complex tasks to computer programs, and engineers' desire to encode as much human operating skill as possible into compliant, untiring, non-salaried machines -- thus relegating the operators themselves to the roles of babysitters and second-guessers.[39] Neither of these jobs suit the abilities of humans, who tend to be bored to stupefaction by routine monitoring tasks, but then paralyzed by information overflow during actual emergencies. "If a group of human factors specialists sat down with the malign intent of conceiving an activity that was wholly ill-matched to the strengths and weaknesses of human cognition," Reason writes, "they might well have come up with something [like] what is currently demanded of nuclear and chemical plant operators."[40]

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[38] Around the same time Wiener wrote these words, however, he adopted a policy of *personal* resistance to the military application of his scientific work. In a 1946 letter of refusal to a Boeing missile designer who had requested copies of his work on prediction and filter theory, Wiener wrote that "the policy of the government itself during and after the war, say in the bombing of Hiroshima and Nagasaki, has made clear that to provide scientific information is not a necessarily innocent act, and may entail the gravest consequences...In any investigation of this kind the scientist ends with the responsibility for having put unlimited powers in the hands of the people whom he is least inclined to trust with their use...I do not expect to publish any future work of mine which may do damage in the hands of irresponsible militarists." The letter is reprinted in "From the Archives," *Science, Technology, & Human Values* (Summer, 1983) 36-38.

[39] On the ways in which military requirements influenced the development of automatic control

All of the easy tasks in facilities like petroleum refineries and power stations have been automated, leaving human operators with only the hardest one: responding to emergencies. Yet nothing in the everyday operation of these plants prepares operators to make the *right* decisions when emergencies actually occur, since accidents, by their very nature, cannot be reliably modeled and simulated beforehand. If they could be, then the proper responses would be programmable and there would be no need for human operators; emergencies are events that evade forethought and automatic control since, by definition, they "emerge" unexpectedly. The paradox is most acute precisely where reliable control is most essential. When the potential deaths from a catastrophic failure can be measured in the thousands -- as is true for nuclear power technology -- elaborate safety systems are an absolutely necessity. Yet the more complex these systems grow, the less chance their human operators have of interceding correctly.

One important function of system failures, then, is to alert citizens to the contradictions and limitations inherent in the idea of computerized

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methods in the United States, see David Noble, *Forces of Production: A Social History of Industrial Automation* (New York: Knopf, 1984).

[40] James T. Reason, *Human Error* (Cambridge, U.K.: Cambridge University Press, 1990) 183.

cybernetic control. "The layman believes that the very fact that a program runs on a computer guarantees that some programmer has formulated and understands every detail of the process which it embodies. But his belief is contradicted by fact," noted Joseph Weizenbaum in his 1976 study *Computer Power and Human Reason*:

> Programming systems can be built without plan and without knowledge, let alone understanding, of the deep structural issues involved, just as houses, cities, systems of dams, and national economic policies can be similarly hacked together. As a system so constructed begins to get large, however, it also becomes increasingly unstable. When one of its subfunctions fails in an unanticipated way, it may be patched until the manifest trouble disappears. But since there is no general theory of the whole system, the system itself can be only a more or less chaotic aggregate of subsystems whose influence on one another's behavior is discoverable only piecemeal and by experiment.[41]

Technological disasters are one kind of "experiment" through which people can come to understand the chaos inherent in complex systems. But why, in the end, should citizens concern themselves with such abstruse matters? Operating large technological systems safely in the face of real-world unpredictability is, after all, what professional engineers, programmers, and managers are paid to do, is it not?

It is, but to limit the question in this way leaves out the crucial fact that large technological systems are more than networks of people and devices. They are also the accumulated result of decades of innovation, negotiation, and investment, and in a democracy it is the right and the responsibility of each new generation to reassess these commitments. Otherwise, the systems are guaranteed to grow aloof, unresponsive to the needs of the people, and perhaps physically dangerous. As Weizenbaum put it, "The reification of complex systems that have no authors, about which we know only that they were somehow given us by science and that they speak with its authority, permits no questions of truth or justice to be asked."[42] What is needed is a general recognition of how swiftly technological control in its modern, cybernetic form can take on the aspect of *political* control.

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[41] Joseph Weizenbaum, *Computer Power and Human Reason: From Judgment to Calculation* (New York: W. H. Freeman and Company, 1976) 119, 234.

The Politics of Large Technological Systems

Many technologies are inherently "political" in the sense that their designs dictate the social conditions under which they may be used.[43] That complex industrial enterprises require a centralized, hierarchical form of social control in order to function efficiently, for example, is now virtually undisputed. In his comprehensive studies *The Visible Hand* and *Scale and Scope*, business historian Alfred Chandler showed that industry's enormous expansion in the United States after the Civil War was made possible by new managerial techniques modeled on military line-and-staff command systems. Field managers reported to middle administrators, who reported in turn to top executives, thus assuring the coordination and economies of scale that would make good on the large investments required to set up such far-flung business empires as railroads, electrical utilities, and chemical companies.[44] No serious reworking of the military-bureaucratic pattern has been attempted since, probably because modern technologies simply require this form of organization if their material possibilities are to be fully exploited. As John Kenneth Galbraith has written, "More perhaps than the machinery, massive and complex business organizations are the tangible manifestations of advanced technology."[45]

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[42] Ibid., 252.

[43] The automobile, for example, has, perhaps more than any other invention in this century, reordered the external world to fit its peculiar character; suburbia, the interstate highway system, and the global petroleum economy all owe their existence to automobility's powerful appeal. The best treatment of this general theme is Langdon Winner's "Do Artifacts Have Politics?," the second chapter in *The Whale and the Reactor: The Search For Limits in the Age of High Technology* (Chicago: University of Chicago Press, 1986) 19-39.

[44] During the nineteenth century, Chandler summarizes, "the firm was the agent making the engine go, putting together resources to distribute technology and affecting the shift from rural agrarianism to urban industrialism." (From author's personal notes on Chandler's remarks at the Workshop on Technological Determinism, Program in Science, Technology, and Society, Massachusetts Institute of Technology, December, 1989.) See also Alfred Chandler, *The Visible Hand: The Managerial Revolution in American Business* , and *Scale and Scope: The Dynamics of Industrial Capitalism* (Cambridge, Mass.: Belknap Press, 1990).

Large-scale undertakings in this century such as rural electrification and the building of the atomic bomb, historians point out[46], have required the creation of powerful "expert bureaucracies" that operate outside democracy's traditional system of checks and balances. Existing to promote and exploit particular technologies, quasi-public organizations like the Tennessee Valley Authority and the Atomic Energy Commission (now the Department of Energy) have gradually assumed overt legislative powers over social affairs.[47] The AEC, for example, nurtured the commercial nuclear power industry in the United States through an expert-driven plant licensing process that was long immune to local opposition, and today TVA ratepayers must shoulder huge yearly interest payments on the $25 billion debt from the agency's failure-ridden nuclear power projects.[48] Understandably, expert bureaucracies often acquire a reputation for arrogance and unaccountability. To quote an executive of one power company -- busy, at the time, slicing through a rural Ohio village with a high-voltage transmission line -- "There are always a few crackpots who feel sentimental about dear old grandfather's place, but we have standard ways of dealing with them...It's easy to force our way through Zilchville."[49]

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[45] John Kenneth Galbraith, *The New Industrial State,* 4th edition (Boston: Houghton Mifflin Company, 1985) 16.

[46] See, for example, Brian Balogh, *Chain Reaction: Expert Debate and Public Participation in American Nuclear Power, 1945-1975* (New York: Cambridge University Press, 1991).

[47] On the history of the AEC and the TVA's involvement in nuclear power, see Balogh.

[48] See Danielle Droitsch, "T.V.A.'s Blighted Nuclear Romance," *The Nation* (June 27, 1994) 906-08.

[49] Quoted in Louise B. Young, *Power Over People* (New York: Oxford University Press, 1973) 185.

While the growth of large, highly organized technological systems has vastly increased the range of goods and services available to the citizens of industrialized nations, it has also surrounded them with a kind of shadow government, one no less influential than the traditional governing institutions of laws, elections, and taxes. The authors of "The Triple Revolution," an open letter to President Lyndon B. Johnson by a group of humanists, economists, journalists, and social activists, warned of this change, which they called the *cybernation revolution*, as early as 1964:

> A new era of production has begun...Its principles of organization are as different from those of the industrial era as those of the industrial era were different from the agricultural. The cybernation revolution has been brought about by the combination of the computer and the automated self-regulating machine... Cybernation is already reorganizing the economic and social system to meet its own needs...The fundamental problem posed by the cybernation revolution in the U.S. is that it invalidates the general mechanisms so far employed to undergird people's rights as consumers. Up to this time economic resources have been distributed on the basis of contributions to production, with machines and men competing for employment on somewhat equal terms. In the developing cybernated system, potentially unlimited output can be achieved by systems of machines which will require little cooperation from human beings.[50]

The writers called for the creation of a network of democratically-run planning institutions "at every level of government" to combat technological unemployment and manage the difficult transition from an economy of scarcity to the "era of abundance" promised by cybernation. These institutions, of course, were never created, since as the authors themselves recognized, "the present system encourages activities which can lead to private profit and neglects those activities which can enhance the wealth and

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For more on the conflict between utility companies and property owners over the right of eminent domain as it applies to the construction of electrical transmission lines, see Barry M. Casper and Paul David Wellstone, *Powerline: The First Battle in America's Energy War* (Amherst, Mass.: University of Massachusetts Press, 1981).

[50] Ad Hoc Committee on the Triple Revolution, "The Triple Revolution" (March 22, 1964), reprinted in Michael Shuman and Julia Sweig, eds., *Technology for the Common Good* (Washington, D.C.: Institute for Policy Studies, 1993) 144-60.

the quality of life of our society."

Langdon Winner argues, similarly, that the technological capabilities of large systems have come to define not only how we work and how our material surroundings are structured, but also what kinds of political goals it is permissible to pursue. The "theory of technological politics" outlined in Winner's study *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (1977) brings together the ideas of social thinkers like Karl Marx, Jacques Ellul, Herbert Marcuse, Lewis Mumford, and John Kenneth Galbraith, and places them in the context of today's fully-realized technological systems. "We continue to talk as if telephone and electric systems were analogous in their employment to a simple hand drill, as if an army were similar to an egg beater," Winner complains. In fact, writers like Ellul and Mumford have already helped us to see that "the total order of networks is anything but neutral or tool-like. In its centrality to the daily activity and consciousness of the 'employee,' the function-serving human component, the technical order is more properly thought of as a way of life."[51]

The original purposes people assign to large technological systems, Winner suggests, tend to be supplanted over time by new goals defined by the systems themselves -- especially their need to secure the proper conditions for their own continual expansion. In a process Winner labels "reverse adaptation," systems attempt to readjust human ends to match their own specialized capabilities, eliminating along the way all independently formulated goals and needs. "Beyond a certain level of technological development, the rule of freely articulated, strongly asserted purposes is a luxury that can no longer be permitted," Winner observes.[52]

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[51] Autonomous Technology, 201-202.

Systems optimize their surroundings by gaining control over relevant markets and regulatory processes, by manipulating human needs through advertising and other methods of persuasion, and by fabricating crises or new missions that match their capabilities and justify expansion.[53] A large industrial corporation like General Electric, for example, protects its diverse interests by securing long-term contracts with government agencies, by lobbying extensively in Washington (making large campaign contributions to favored members of Congress, scuttling some laws and helping to write others), by controlling national media outlets, and by representing itself as the political voice for hundreds of thousands of employees and others whose livelihoods depend on the company's fate.[54] Given the sheer size of organizations like GE, NASA, or the Department of Defense -- organizations that *must* wield political influence in order to hold together their sprawling technological empires -- it is not surprising that national politics has become a game too expensive for average citizens to play.

Yet the style of governance that results is neither elitist nor cabalistic. It bears little resemblance to various social theories about the "establishment," the "power elite," or the "technostructure."[55] Instead the fulfillment of each large system's technical and economic requirements adds to a set of demands on a society's overall resources that eventually *becomes* the society's political agenda. "To ignore these demands, or to leave them insufficiently fulfilled, is to attack the very foundations on which the modern social order rests," Winner writes.[56] In such a technological order, a citizen's role is principally to "serve one's own function and not meddle with the mechanism."[57]

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[52] Ibid., 238.

[53] Ibid., 242-49.

[54] A leading producer of everything from jet engines to medical imaging equipment, nuclear weapons to financial services, General Electric owns 177 plants in the United States and employs 243,000 Americans. For an analysis of GE's political style, see Chapter 15 of William Greider's *Who Will Tell the People: The Betrayal of American Democracy* (New York: Touchstone, 1993) 331-55.

[55] See C. Wright Mills, *The Power Elite* (New York: Oxford University Press, 1956); Galbraith, *The New Industrial State.*

While not specifically concerned with technology's social effects, William Greider's recent catalog of the major forces eroding traditional notions of citizenship, *Who Will Tell the People: The Betrayal of American Democracy* (1992), continues Winner's argument. The success of large, powerful organizations in making government into the instrument of their own needs, Greider contends, has drained democracy of its essential meaning. The citizens who appear in Greider's book say they have learned through practical experience -- in conflicts over the environment, education, taxation, nuclear arms, food safety, and dozens of other issues -- that "the law is not on our side," as one environmental activist put it.[58] Unable to compete with monied interests for the attention of their elected representatives, unprotected by political parties, labor unions, and the other mediating institutions that once represented them, and left to watch helplessly as controversial policy issues become engulfed in the expert-dominated state and federal bureaucracies, many middle- and working-class people have developed a poisonous contempt for government, Greider believes. "The political culture that fractured governing authority and allowed political institutions to become irresponsible has done the same to the citizenry," he writes.[59]

Greider offers this discouraging but accurate summation of the state of democratic politics in the United States today: "Behind the reassuring facade, the regular elections and so forth, the substantive meaning of self-government has been hollowed out...Citizens are cut out of the politics surrounding the most important governing questions. The representative system has undergone a grotesque distortion of its original purpose. The connective tissues that once linked ordinary people to governing no longer function reliably...In sum, the mutual understanding between citizens and government necessary for genuine democracy is now deformed."[60]

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[56] *Autonomous Technology,* 258-59.
[57] Ibid., 207.
[58] Greider, *Who Will Tell the People,* 166.
[59] Ibid., 162.

One major force causing this deformation, I believe, is the political power of large technological systems. Whether in the form of the corporation, the quasi-public authority, or the government agency, these systems continually attempt to reduce citizenship to a controllable variable in the technological universe of inputs and outputs. Here is how one system manager, Theodore J. Nagel of the American Electric Power Service Company of New York, has described the need to curb and contain citizen participation in his system's activities:

> Public concern and involvement in the siting process is essential in a free society. In a complex, industrialized (but orderly) society, however, complex issues require the application of specialized knowledge by those trained and experienced. In other words, a specialized technical activity such as power system planning cannot be carried out in an open forum or in the atmosphere of a town hall. This means that the entire intervention process needs to be circumscribed by certain rules...The alternative can be nothing less than confusion and chaos.[61]

Lest the reader think that this is the attitude of a small, defensive group of industrial leaders, consider what John Kemeny, then president of Dartmouth College, came to believe about the American democracy after his experience as head of President Carter's commission to investigate the accident at Three Mile Island. In an address at MIT, Kemeny declared that "Jeffersonian democracy cannot work in the year 1980 -- the world has become too complex...The only way to save American democracy is to change the fundamental decision-making process, at the federal level, so that it can come to grips with the enormous and complex issues that face this nation." Kemeny advocated the creation of expert panels of scientists and engineers to craft solutions to major social problems.[62] He concluded, "I trust democracy -- the president and Congress -- to choose among [these solutions]; but I do not trust democracy to try to put [them] together."[63]

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[60] Ibid., 11-12.

[61] Theodore J. Nagel, "Operating a Major Electric Utility Today," *Science* (Sep. 15, 1978) 985-93. The use of the word "intervention" to describe citizen attempts to participate in technological decision-making underscores the extent to which -- in language, thought, and political reality -- the prerogative to plan in industrialized societies has been ceded to those managing large technological systems. On the politics of siting controversies, see especially the work of Dorothy Nelkin: *Nuclear Power and Its Critics: The Cayuga Lake Controversy* (Ithaca, N.Y.: Cornell University Press, 1971); *Jetport: The Boston Airport Controversy* (New Brunswick, N.J.: Transaction Books, 1974); *Controversy: Politics of Technical Decisions* (Beverly Hills, Calif.: Sage Publications, 1979).

On one level, what Nagel, Kemeny, and many others have asserted about the complex nature of industrialized societies is perfectly sensible. The comfort and security of modern social life -- as compared to the drudgery and brevity of life in traditional societies -- rest on the smooth operation of innumerable systems for the sharing of energy, products, and information across great distances. "Even the smallest of neighborhood stores probably obtains its goods from all over the world," as Anthony Giddens observes.[64]

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[62] Kemeny, a mathematician by training, was by no means the first scientist to propose reforms strengthening the role of expertise in government. The physicist Robert Millikan, as early as 1932, proposed a "scientific jury system" to discover the true "social facts" on which policies to end the Depression could be built. See Dorothy Nelkin, "Controversies and the Authority of Science," in H. Tristram Engelhardt Jr. and Arthur L. Caplan, eds., *Scientific Controversies: Case Studies in the Resolution and Closure of Disputes in Science and Technology* (Cambrdige, U.K.: Cambridge University Press, 1987) 283-93.

[63] Kemeny's address was reprinted as "Saving American Democracy: The Lessons of Three Mile Island," *Technology Review* (June/July, 1980) 65-75.

[64] Giddens continues, "Every time someone gets cash out of the bank or makes a deposit, casually turns on a light or a tap, sends a letter or makes a call on the telephone, she or he implicitly recognizes the large areas of secure, coordinated actions and events that make modern social life possible...Trust in abstract systems is a condition of time-space distanciation and of the large areas of security in everyday life which modern institutions offer as compared to the

We *do* entrust the operation of these extended systems to people with special knowledge, training, and experience, because the systems could not operate otherwise; a carpenter would make a very poor air traffic controller, and a kindergarten teacher a bad jet pilot. It would seem to follow from this fact that solutions to the novel social dilemmas generated by these systems' growth can only be discovered and elaborated by those with a thorough command of the systems' complexities.

Against this brand of technocracy, however, there are three strong arguments. First, no guarantee exists that the "solutions" crafted by scientific and technical experts will be those that best serve the social good[65] rather than those that merely serve the technical and economic requirements of the systems the experts represent.[66] "Even in their highly mathematical or technical garb," writes Ulrich Beck, the cost-benefit analyses constructed by experts "contain statements of the type *That is how we want to live* -- statements, that is, to which the natural and engineering sciences alone can provide answers only by overstepping the bounds of their disciplines."[67] The U.S. experience with commercial nuclear power, examined in detail in Chapter 3, is a case in point. Driven by Cold War fears, Congress delegated

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traditional world." *The Consequences of Modernity* (Cambridge, U.K.: Polity Press, 1990) 109, 113.

[65] As defined by the members of society themselves, through whatever democratic means available.

[66] This is, of course, a version of the venerable Marxist critique of industrial capitalism. As David Harvey writes, "The disciplining of labor power to the purposes of capital accumulation...is a very intricate affair. It entails some mix of repression, habituation, co-optation and co-operation, all of which have to be organized not only in the workplace but throughout society at large. The socialization of the worker to conditions of capitalist production entails the social control of physical and mental powers on a very broad basis." *The Condition of Postmodernity: An Enquiry into the Origins of Cultural Change* (Oxford, U.K.: Basil Blackwell Ltd., 1989) 123.

[67] Ulrich Beck, *The Risk Society: Towards a New Modernity* (London: Sage Publications, 1986) 58.

responsibility for the development and regulation of nuclear power to nuclear engineers, utility planners, and their counterparts in the Atomic Energy Commission and its successor, the Nuclear Regulatory Commission. The result today is a technology so crippled by public mistrust and economic woes that some utilities are attempting to dispose of their reactors at fire-sale prices[68] and even nuclear experts acknowledge that one more accident on the scale of Three Mile Island would likely mean the shutdown of the industry.[69]

Second, proponents of technocratic rule dismiss too quickly the possibility of thoughtful, rational, informed public participation in complex technological issues. While it is indeed true that in order to understand all of the workings of a nuclear reactor a Ph.D. in physics and/or nuclear engineering is required, the basic technical facts of nuclear power -- most importantly for the present study, the relationship between a reactor's complexity and its vulnerability to catastrophic breakdown -- are well within the grasp of the average lay person. A number of social-scientific studies have confirmed this general point. After showing groups of lay people short films on technological problems such as global warming and solid-waste disposal and then conducting 45-minute discussion sessions, for example, researchers John Doble and Amy Richardson found that participants' comprehension of technical details, as measured by before-and-after surveys, increased by 50 percent. The study participants also grew more confident in their assessments of possible practical solutions, and their final policy choices corresponded closely with those preferred by leading scientists whom Doble and Richardson contacted. "A lack of detailed scientific knowledge does not block most people from carefully assessing complex issues," the two researchers concluded.[70] What *does* block people from participating in such assessments is the myth, formulated by technical elites and ratified by expert-dominated government and industry bodies, that they are uninterested and ineducable.

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[68] The Washington Public Power Supply System sold two $4 billion plants for scrap, netting $10 million, and is now trying to sell another two plants, backed by $9.25 billion in bonds, for their $50 million to $100 million salvage value. See Leslie Eaton, "Utility Trying Hard to Sell Reactors," *The New York Times* (July 14, 1994) D1, D19.

[69] The National Research Council's Committee on Future Nuclear Power Development warned in 1992, "Public policy makers...shoul be concerned about the level of accident prevention measures because another accident like that at TMI in the near future would seriously affect the future of nuclear power in the United States." Nuclear Power: Technical and Institutional Options for the Future (Washington, D.C.: National Academy Press, 1992) 61.

The third argument against technocratic social control, and the one most pertinent to this study, is that *experts themselves can never possess complete knowledge of the behavior of complex systems.* Any claim to such knowledge must itself be a carefully cultivated fiction, as control breakdowns make clear. "In nearly every investigation of accidents and their precursors...one finds the same situation," Brian Wynne writes. "Beneath the public image of rule-following behavior, and the associated belief that accidents are due to deviations from those clear rules, experts are operating with far greater levels of ambiguity, needing to make uncertain judgments in less than clearly structured situations."[71] There is more to this than the fact that experts, like all humans, occasionally fall victim to error or to their own ignorance of the "expertise" they are presumed to possess. Catastrophes help to demonstrate, instead, that *perfect expertise cannot exist*: a kind of Gödel's

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[70] John Doble and Amy Richardson, "You Don't Have to Be a Rocket Scientist..." *Technology Review* (January, 1992) 51-54. The authors also found that the times when the lay citizens disagreed with scientists, as in the case of nuclear power, had no correlation with low comprehension scores. Moreover, the same number of respondents were opposed to nuclear power after the presentations as before, even though the presentations emphasized that nuclear power does not contribute to global warming. The authors compared citizens' position on nuclear power to the view that "no matter how many safety features it has, a car is unsafe if the driver is incompetent." Citizen opposition, they suggested, is a product of well-founded mistrust of nuclear designers, operators and regulators.

[71] Wynne, "Unruly Technology," 153.

Incompleteness Theorem for technology.[72] Giddens is precisely correct in this matter: "There is no skill so carefully honed and no form of expert knowledge so comprehensive that elements of hazard or luck do not come into play. Experts ordinarily presume that lay individuals will feel more reassured if they are not able to observe how frequently these elements enter into expert performance."[73] To the extent that hazard or luck are part of any complex social or technological system, therefore, the qualifications of experts for the roles of ethicist and policy-maker are no stronger than those of lay citizens.

That the technocratic world-view remains persuasive to many people, however, demonstrates the ongoing success of large technological systems in transforming the cultures and the political frameworks in which they are embedded. These systems have not just helped to destroy the old "connective tissues" linking citizens and government; they have *become* those tissues, replacing old mediating institutions like labor unions and an independent press with faceless bureaucracies expert at representing their own interests as those of the citizenry at large. In reality, large technological organizations do not transmit democratic impulses so much as dampen and disperse them. As Winner writes, "If some perverse spirit set out deliberately to design a collection of systems to increase the general feeling of powerlessness, enhance the prospects for the dominance of the technical elites, create the belief that politics is nothing more than a remote spectacle to be experienced vicariously, and thereby diminish the chance that anyone would take democratic citizenship seriously, what better plan to suggest than that we simply keep the systems we already have?"[74]

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[72] Kurt Gödel was the mathematician who demonstrated in the nineteen-thirties that no mathematical system can be sufficiently sophisticated to prove its own basic hypotheses.

[73] Giddens, *The Consequences of Modernity*, 86-87.

Catastrophes: A Chink in the Armor

As failures that start small and shatter outward through nested spheres of control, technological catastrophes open large systems to unwelcome meddeling from the outside. The loss of control often begins well before an actual accident, in the form of design oversights, maintenance errors, miscommunication, poor regulation, and other mistakes that remain latent in the system until activated by some mechanical or electronic malfunction. As warnings are misinterpreted, safety devices misfire, and large amounts of energy are misdirected, operators may then lose control over the system itself. The loss soon spreads to the outside environment, threatening bystanders with injury, death, or disruption. If public grows sufficiently angry over the threat, finally, the system may lose some of its accustomed power over the society's political agenda. In this way, the "rule of freely articulated, strongly asserted purposes" may be partially restored.

We have seen how complexity, tight coupling, computerization, and increased risk-taking with improved technology contribute to uncertainty in large technological systems. Disaster researchers and organizational sociologists attempting to explain the current proliferation of technological hazards also point to two other basic trends in industrial innovation:

Older Technologies on a Larger Scale. Maturity does not always confer reliability. Though much safer than in the past, some of the most ancient industrial activities, such as mining, logging, and marine shipping, are still among the most hazardous. And certain enterprises that originated before

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[74] *Autonomous Technology*, 325.

World War II, especially chemical manufacturing, have lately become so central to the industrialized world's high-production, high-consumption way of life that they have acquired a new and portentous omnipresence. "When we started research about 40 years ago, chemical disasters were simply not mentioned as a major or frequent risk," writes Henry Quarantelli, a sociologist at the University of Delaware's Disaster Research Center. Since then, "the incidence of chemical emergencies and disasters has continued to increase around the world...Even localities which in the past had none or few risks are now vulnerable if they have any roads, railways, or navigable waterways in the vicinity of toxic chemical spills, explosions, or fires."[75] Size, in other words, has its drawbacks. It is seldom possible to carry out an old activity on a vastly increased scale without also multiplying its hazards.

Globalized Networks. A process of invention that began with smoke signals and semaphores has brought humanity into the age of global interconnectivity. Telegraphs, telephones, computer networks, radio and television link us together electronically, just as roads, highways, water mains, sewers, pipelines and the electrical grid link us physically. But AT&T's telephone-network glitches and the Salomon Brothers computer-trading fiasco show that these networks allow undesired effects to spread just as quickly as desired ones. In 1965, a single overloaded circuit breaker in Queenston, Ontario, triggered a series of power failures that blanketed the entire Northeastern United States in darkness (see Chapter 2). In 1988, Cornell computer science student Robert Morris Jr. released a self-replicating "worm" designed to hide harmlessly within the memories of computers linked to the Internet. An error in the program caused it to run amok, jamming more than 6,000 computers nationwide.[76] In short, it has become dificult to safeguard oneself, one's family, or one's business from the effects of breakdowns kilometers or continents away.

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[75] E. L. Quarantelli, "More and Worse Disasters in the Future: The Social Factors Involved," Preliminary Paper #173 (Delaware, Maryland: University of Delaware Disaster Research Center, 1991) 5-6.

Given that the deep-rooted trends toward greater complexity, tight coupling, computerization, risk-taking, size and globalization are unlikely to reverse themselves soon, it is a good bet that there will be "more and worse disasters in the future," as Quarantelli puts it. We can be certain, at least, that it will never be possible to eliminate technological breakdowns altogether. Ultimate safety is a chimera, a forever-postponed promise made by technologists (including, for example, the designers of the vaunted "next generation" of "inherently safe" nuclear reactors) to mollify a distrustful public.

But perhaps this situation is not as desperate as it sounds. Engineers argue that "failure analysis," the technical study of technological disasters, is both a useful way of detecting design flaws and a spur to safety-improving organizational and regulatory reforms.[77] I propose that disasters are an important source of revelation not just about how particular technologies work but about *the way technological society operates.* Without these occasional shocks, citizens would have fewer opportunities to learn about large technological systems and to assess their compatibility with important political values. We need not welcome -- and it would be folly to *encourage* -- disruptive and harmful technological breakdowns. But we would not be very good experimentalists if we let these episodes pass without examining them for their social lessons. We all have a stake in the outcome of these exercises in "technopathology."

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[76] John Markoff, "Keeping Things Safe and Orderly In the Neighborhoods of Cyberspace," *The New York Times* (Oct. 24, 1993) IV:7.

[77] See James L. Adams, *Flying Buttresses, Entropy, and O-Rings: The World of an Engineer* (Cambridge, Mass.: Harvard University Press, 1991); Henry Petroski, *To Engineer Is Human* (New York: St. Martins Press, 1985).

Failures are as varied in their origin and character as the technologies they strike, but the strain I have been describing, the large-technological-system breakdown, stands out as particularly problematic and meaningful. It is this kind of failure that most upsets assumptions about the imperviousness of large, complex systems, and for that reason I would like to christen it Winner's Apraxia.

Apraxia is a neurological term describing the inability to use sensory information to coordinate bodily movements. Apraxic patients, usually the victims of brain lesions, cannot carry out everyday motor tasks such as opening doors or eating with silverware. They may grope about or gesture grotesquely when asked to salute or flip a coin; they may be able to dress themselves on one side of their bodies, but not the other. Interestingly, a person with apraxia *sees, hears* and *understands* sensory cues, but the neural pathways which usually transmit commands from the visual and auditory cortices to the motor cortex or from one hemisphere of the brain to the other are somehow blocked. The right hand literally does not know what the left is doing. Worse, it has no way of reestablishing communications.[78]

The unique properties of this disorder have made it an irresistible metaphor for trouble in other kinds of complex systems. Langdon Winner adopted it in *Autonomous Technology* to describe the loss of control and coordination in large systems such as the electrical grid or the air-traffic-control network. "If a significant link in a technical system ceases to function, the whole system is thrown into chaos...In large-scale technical networks composed of artificial components with complex interconnections and interdependencies, apraxia is a constant danger."[79] Just as an apraxic patient's brain injury makes it difficult for him to dress, eat and generally coordinate sensory impressions with bodily actions, control breakdowns leave large technological systems without the nervous systems they need to transfer information between their sensors and effectors. Blackouts, telephone system failures, nuclear plant shutdowns, and computer errors threaten modern society with literal dis-integration. "The technological order is one in which all systems are 'go' and indeed must be," Winner notes. "The alternative is disaster for technology-dependent human populations....In visions of technological society, apraxia...is the ultimate horror, a condition to be avoided at all costs."[80]

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[78] Erick R. Kandel and James H. Schwartz, *Principles of Neural Science, Second Edition* (New York: Elsevier Science Publishing Co., 1985) 499, 698-699.

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[79] Langdon Winner, *Autonomous Technology* (Cambridge, Mass.: MIT Press, 1977) 186. It should be noted that certain globalized networks -- the Internet is the paradigmatic example -- are designed precisely so that the failure of one node will *not* throw the system into chaos. (In the case of Arpanet, the core network from which the Internet grew, this was important because it conferred survivability in a nuclear war.) Internet is, in a sense, a chronically apraxic technological system -- what Thomas Hughes has called a "postmodern" system (Thomas P. Hughes, "Postmodern Engineering," Arthur C. Miller Lecture on Science and Ethics, Massachusetts Institute of Technology, April 8, 1993).

[80] Ibid., 186-87. Victor McElheny writes in rejoinder, "A good way to horrify people would be to describe what happens normally every minute in these systems (electrical grids, air traffic control, and so on). They would reel at the complexity, the near-misses, etc. And yet it can be claimed that the day-to-day reliability continues to increase to nearly incredible levels...Normal accidents, indeed! Normal highwire success is more like it." (Personal communication, June 8, 1994.) Todd LaPorte and Paula Consolini expand on this celebratory theme in an article on so-called 'high-reliability organizations' entitled "Working in Practice But Not in Theory." They write, "From the literature [in organizational sociology] one cannot expect that sustained failure-free performance is possible, even to a moderate degree. Yet there are large-scale, highly complex organizations that have taken up this goal and almost always achieve it." (Todd M. Laporte and Paula R. Consolini, "Working in Practice But Not In Theory: Theoretical Challeges of 'High-Reliability Organizations,'" *Journal of Public Administration Research and Theory* ,Vol. 1, No. 1, 1991, 19-47.) McElheny, LaPorte, and Consolini are all correct that large systems nearly always work well, but the emphasis in *this* study is on the "nearlys" and the "almosts." When these 'high-reliability organizations' do fail, they fail spectacularly, and it is legitimate to examine the systemic problems thus revealed.

No one welcomes catastrophe. But might technological apraxia, as I have been arguing, actually possess qualities worth studying? To find out, let us follow the metaphor a bit farther. As a neurological condition, apraxia is unfortunate but not life-threatening. Patients who are unable to carry out a command using verbal cues are often successful when they switch to visual ones, or vice-versa. Moreover, there is very little that can be done about apraxia; once cerebral damage has occurred, neurologists are usually limited to diagnosing it. Given that there will always be a certain number of apraxic patients, it would be a shame if neuropathologists did not use this opportunity to learn how lesions in the brain affect language processing and motor performance. Studies of these patients have, in fact, helped to establish that the brain hemisphere that is dominant for language is also dominant for learning skilled movements, since a lesion in the dominant hemisphere prevents an apraxic patient from carrying out verbal commands with either hand but a lesion in the non-dominant hemisphere disables only one hand or, more often, neither.[81]

Technological apraxia can be a similarly rich source of insight for "technopathologists." Just as the physician's highest obligation under the Hippocratic Oath is to do no harm, there is, as Winner warns, a kind of "moral imperative" that views any attempt to disturb the technological order as positively malicious.[82] But technological breakdowns, like sickness, occur without human intention. Our best efforts to keep major systems in working order are often inadequate, so that there is a constant supply of interesting mishaps. (William McNeill goes so far as to suggest that a "law of the conservation of catastrophes" rules human affairs.[83]) We would be remiss if we failed to investigate the social and political implications of these breakdowns, just as the neurologist who ignored the effects of injury would forfeit valuable information about the brain's normal functioning. The revelatory power of technological disasters is that they show attentive observers how technological society works from the inside out -- creating the opportunity for reflection and change.

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[81] Richard L. Strub and F. William Black, *The Mental Status Examination in Neurology, Second Edition* (Philadelphia: F.A. Davis Company, 1985) 142.
[82] Winner, 187.

The usual impulse following almost any kind of technological failure, whether it be a plane crash or a phone-system crash, is meliorist: Launch an investigation, discover the cause of the failure, repair or replace the flawed components, chastise those who may have contributed to the failure, then get on with life. There is a powerful logic to this approach. It is, after all, the way hazardous technologies are made safer. We need not discard the world fleet of DC-10 jets after only a few accidents, much less give up telephones after a few calls fail to get through. Next time we will do better.

But if the quick-repair response becomes wholly automatic -- if, as Winner suggests, the slightest disturbance to the technological order is seen as *intolerable* -- then something valuable has been forfeited. It is the willingness to have our assumptions jarred, the opportunity to re-evaluate how technological systems *should* behave in light of how they *mis*behave. Winner coined the phrase "epistemological Luddism" to describe the voluntary, systematic interruption of certain links in the technological order; such an activity might be undertaken, he wrote, "as an opportunity to inquire, to learn, and to seek something better...What is the institution doing in the first place? How does its technological structure relate to the ends one would wish for it? Can one see anything more than to plug the whole back together the way it was before?"[84] Winner says he never expected to see epistemological Luddism applied as an exercise in the real world; he proposed the idea mainly because it was certain to be dismissed as impractical, thus illustrating exactly how strong the meliorist mindset has grown. "It was an impish proposal that I offered, instead of a proposal for reform, precisely to get people to see how deeply enmeshed we are and how deeply our ability to make choices and decisions has been given over to systems and arrangements that are almost impossible to change," he explains.[85]

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[83] McNeill writes, "It certainly seems as though every gain in precision in the coordination of human activity and every heightening of efficiency in production were matched by a new vulnerability to breakdown. If this really is the case, then the conservation of catastrophe may indeed be a law of nature like the conservation of energy." "Control and Catastrophe in Human Affairs," 11-12.

But conditions of technological disorder that we would never endure voluntarily, precisely because they are so disruptive, come along once in a while whether we like it or not. We may as well take advantage of them. As Winner concluded in *Autonomous Technology,* "The best experiments can be done simply by refusing to repair technological systems as they break down."[86]

Lewis Mumford offered a similar idea in *The Myth of the Machine.* "Half a century ago H.G. Wells observed, correctly enough, that mankind faced a race between education and catastrophe," Mumford wrote in 1964. "But what [Wells] failed to recognize was that something like catastrophe has become the condition for an effective education. This might seem like a dismal and hopeless conclusion, were it not for the fact that the power system, through its own overwhelming achievements, has proved expert in creating breakdowns and catastrophes."[87]

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[84] Winner, *Autonomous Technology,* 332-333.
[85] Telephone interview with Winner, November 4, 1992.
[86] Ibid., 333.

Mumford, like Winner, failed to explore the implications of his remarks. What kinds of breakdowns can be educational? How do the lessons of catastrophe take hold and spread through society? How, in the end, is the "power system" itself transformed by this process? These are the some of questions I hope to answer in the following chapters. One of my goals is to demonstrate that a technological disaster's *technical* details cannot be disentangled from its *political* significance. More specifically, I want to show that "citizen technopathologists" can put the lessons learned from technological disasters to use in local and national conflicts over issues of health, safety, and democratic participation. I will argue that many of the critical decisions preceding severe disasters are social, political, or economic in nature, rather than simply technical, and that the final meaning of many disasters rests as much on lay people's interpretations of events as on the interpretations of scientists, engineers, and politicians.

Risk, Social Movements, and NIMBYism

Especially since Love Canal and Three Mile Island, a rapidly growing body of historical and social-scientific work has focused on technological hazards. Three general concepts -- risk perception, social movement theory, and the "Not-In-My-Back-Yard" label -- have structured and informed the bulk of this scholarship. Before going on to the case studies, I must explain why this investigation is *not* about any of these ideas, and why I am arguing for a less theoretical, more event-centered understanding of technological breakdowns and their political consequences.

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[87] Lewis Mumford, *The Myth of the Machine: The Pentagon of Power* , (New York: Harcourt, Brace, Jovanovich, 1964) 409.

Citizen opposition to nuclear power and other hazardous technologies has often been derided by technical experts and industry advocates as a product of misinformation, irrationality, and emotionalism. Reams of analysis in the fields of risk assessment, risk management, risk perception, and risk communication have attempted to explain why the average non-scientist's estimates of the dangers associated with particular technological activities never seem to coincide with analysts' careful mathematical models of the "actual" risks. Most puzzling to these analysts is the fact that people consistently say they dread low-probability/high-consequence hazards such as reactor meltdowns more than high-probability/low-consequence events such as auto accidents.[88]

I believe, however, that people have a considerably subtler grasp on the nature and magnitude of most technological hazards than they are typically given credit for. Most analyses of risk reduce the definition of the "rational" evaluation of hazards to the mathematical comparison of failure probabilities. As Sheldon Krimsky and Alonzo Plough have pointed out, many risk assessors "merely categorize 'irrationalities' and do not explore the cultural underpinnings of risk perception." Risk analysts' studies, Krimsky and Plough explain, ignore the crucial difference between *technical rationality*, resting on the scientific method, objective inputs, and logical consistency, and *cultural rationality*, resting on people's real, subjective experiences of technological or other hazards.[89] "To understand the measure of a risk, you have to understand its history," says Mark Sagoff, director of the Institute for Philosophy and Public Policy. "No risk that is involuntary, illegitimate, unreasonable or unfair might be too small to be resented."[90]

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[88] See, for example, Sarah Lichtenstein, et al., "Judged Frequency of Lethal Events," *Journal of Experimental Psychology: Human Learning and Memory* (1978) 551-78; Paul Slovic, Baruch Fischhoff, and Sarah Lichtenstien, "Perception and Acceptability of Risk from Energy Systems," in William R. Freudenburg and Eugene A. Rosa, eds., *Public Reactions to Nuclear Power: Are There Critical Masses?* (Washington, D.C.: American Association for the Advancement of Science, 1984) 115-35; Roger E. Kasperson, "The Social Amplification of Risk: Progress in Developing an Integrative Framework," in Sheldon Krimsky and Dominic Golding, eds., *Social Theories of Risk* (Wesport, Conn.: Praeger Publishers, 1992) 152-78. The Krimsky & Golding volume contains 14 other essays representing a range of recent work on risk perception, risk assessment, and risk management.

But is "cultural rationality" truly rational? On this matter I share the perspective of Harry Otway, an engineer and social psychologist who observes that "ordinary people are pretty good at acting in accordance with their own beliefs and values to attain their own goals...People do not necessarily behave in a highly efficient way to satisfy their goals but, in the long run, they do manage to muddle through quite well."[91] The factors ordinary people take into account in assessing risk are highly reasonable, even if they cannot be expressed mathematically. "People are concerned about much more than the level of risk to which they will be exposed," Otway writes. "They also care about qualitative aspects, such as who is exposed, who gets the benefits, what social institutions are favored by the particular technology, how the risk will by physiologically manifested, what the catastrophic accident potential is, which effects are delayed, and so on."[92]

"Risks," in other words, are not disembodied mathematical quantities; they are personalized threats carrying physical, emotional, and political significance for those being threatened. Risk analysts, however, treat the public as if they were a bus full of amnesiacs, driving around in circles because they never remember where they have been and gaping at each piece of scenery as if they were seeing it anew. They fail, in other words, to recognize the role of memory and experience in shaping the public's technological preferences. As Krimsky and Plough write, "Cultural rationality can only be understood when people's cognitive behavior is observed *as they are threatened by an actual risk event.*"[93] A set of impressions as powerful as those provided by the disasters discussed in this thesis can be virtually impossible to counteract; the public's trust in a technology and its overseers, once revoked, is likely to be withheld for a very long time. People learn from the mistakes of others as well as from their own.[94]

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[89] Sheldon Krimsky and Alonzo Plough, *Environmental Hazards: Communicating Risks as a Social Process* (Dover, Mass.: Auburn House Publishing Company, 1988) 304-306.

[90] Sagoff's comment is from *Knowing Our Place: Challenges to Citizenship in a Technological Age*, Program II: "Risk, Rationality, and Realpolitik," a live interactive television program produced by David Tebaldi of the Massachusetts Foundation for the Humanities and broadcast by the Massachusetts Corporation for Educational Telecommunications on May 5, 1994.

[91] Harry Otway, "Public Wisdom, Expert Fallibility: Toward a Contextual Theory of Risk," in Krimsky and Golding, eds., *Social Theories of Risk*, 216-28. Otway adds wryly, "The idea that people behave rationally is not uncommon in many social science disciplines, such as social psychology, socioloyg, and anthropology."

[92] Ibid.

One element from the literature on risk, the concept of "availability bias," is particularly treacherous for anyone trying to understand people's reactions to technological disasters. The basic idea, that "an event is judged to be likely if instances of it are easy to imagine or recall,"[95] seems to coincide closely with what I have just described as the "crucial role of memory and experience." It is true that people form judgments about the danger or safety of particular technological systems on the basis of their prior knowledge and experience of these systems. On closer inspection, however, the concept of availability bias turns out to be yet another way of discrediting people's understanding of technological threats. Barbara Combs, Baruch Fischhoff, Sarah Lichtenstein, and Paul Slovic have argued that people consistently overestimate the frequency of spectacular, dramatic, or sensational kinds of lethal events (e.g., industrial accidents, tornadoes, and floods) and underestimate the frequency of those that claim few victims at a time (lightning, stroke, diabetes). The most overestimated hazards, they argue, are those which receive what they term a "disproportionate" amount of media coverage.[96] Following this logic, they claim that citizen opposition to nuclear power results not from the fact that deficiencies in reactor safety have led to real catastrophes, but from the "availability" of disembodied "instances" like Three Mile Island and Chernobyl in some psychological realm of media-manipulated images. People's perceptions of risk, these and many other analysts conclude, are more the product of their values, beliefs, and personality types and of media sensationalism than of any objective process of learning and experience: This is, in short, an intellectualized restatement of the old bias against cultural rationality.

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[93] Krimsky and Plough, 305.

[94] Trust and mistrust in large technological systems will be examined further in the Conclusion.

[95] Slovic et al., "Perception and Acceptability of Risk from Energy Systems," 117.

A full critique of the concept of risk as scholars and technical experts use it today could fill many pages. Here, however, I want to argue that when applied outside the narrow tasks for which it was developed -- principally, gauging the relative reliability of various components of nuclear reactors and their safety systems -- risk assessment becomes a form of scientism, a mathematical construct lending specious authority to business and government decisions about the hazards to which the general population should be subjected. Indeed, the real question might not be whether *cultural rationality* is truly rational, but whether *technical rationality* is. As I argued a few pages ago, experts can never possess complete knowledge of the behavior of complex technologies. Risk assessors who purvey their calculations as objective truth not only ignore the tentative nature of all scientific results, but conceal from the public the considerable uncertainties, mathematical shortcuts, and simplifying assumptions that go into their quantitative estimates. As one physicist put it,

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[96] Paul Slovic, Baruch Fischhoff, and Sarah Lichtenstin, "Rating the Risk," *Environment* (21: 1979) 14-39; Barbara Combs and Paul Slovic, "Newspaper Coverage of Causes of Death," *Journalism Quarterly* (4:1979) 837-43, 849; see also Allan Mazur, "Media Influences on Public Attitudes Toward Nuclear Power," in Freudenburg and Rosa, eds., *Public Reactions to Nuclear Power*, 97-114.

> The expert community is divided about the conceivable realism of probability estimates [regarding reactor accidents] in the range of one in ten thousand to one in one billion per reactor year. I am among those who believe it to be impossible *in principle* to support numbers as small as these without convincing theoretical arguments...The reason I hold this view is straightforward: Nuclear power systems are so complex that the probability that the safety analysis contains serious errors...is so big as to render meaningless the tiny computed probability of an accident.[97]

Risk estimates may still be useful for identifying the most worrisome routes to failure in facilities like nuclear and chemical plants,[98] but people's assessments of the dangers in their lives flow from their knowledge of real, historical hazards, not from mathematical comparisons. What we require if we are to uncover the cultural and political meanings of technological catastrophes, therefore, are portrayals of disasters rich in narrative, ethnographic, *and* technical detail. To the extent that accounts of real disasters highlight the artificiality of the discourse about risk, they clear the air for honest public conversations about technological choices. In what follows, therefore, I will use the terms "risk" and "risky" very rarely, and then only in the vernacular sense of danger, peril, or probability of loss.

At the opposite extreme from studies of the mathematics of risk are analyses that place citizen responses to technological hazards within the framework of one or another theory about social movements and how they arise, succeed, and fail. While social movements have always been powerful forces behind social and political change, social movement *theory* suffers from a highly blinkered view of participants' motivations. Social constructionism, resource mobilization theory, entrepreneurial theory, New Class theory, Jurgen Habermas' neo-Marxist theory and other schools of thought attempt to explain people's participation in modern social movements as the product of their own interests, values, world-views, and class allegiances.[99] Feelings of "relative deprivation" and envy for the power of privileged classes play an especially large part in these explanations.

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[97] John P. Holdren, "The Nuclear Controversy and the Limitations of Decision Making by Experts," *Bulletin of Atomic Scientists* (32: 1976) 20-22.

[98] See, for example, Carnegie Mellon University engineering professor M. Granger Morgan's very circumspect treatment, "Risk Analysis and Management," *Scientific American* (July, 1993) 32-41.

Sociologists Frances McCrea and Gerald Markle, for example, assert in their study of nuclear weapons protest in the United States that "characteristics of advanced capitalistic society have created a new class that increasingly comes in conflict with the old ruling class over the management of society." True enough; the growth of universities in this century has given rise to a large group of humanistic and technical intellectuals equipped to challenge the ruling traditions. But in McCrea and Markle's view, it is this group's "shared grievances, collective interests, and common values and beliefs...[that] lead to a questioning and critiquing of the existing order. Awareness of relative deprivation (in terms of repute, power, and income) increases alienation from the ruling apparatus."[100] Objective threats to health, safety, and democratic representation posed by technologies like nuclear weapons and nuclear power are reduced in this view to "grievances" that launch, but do not explain, conflicts that are essentially about class privilege.

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[99] For a succinct summary of these various schools, see Ch. 1, "Social Movements in Postindustrial Society," in Frances B. McCrea and Gerald E. Markle, *Minutes to Midnight: Nuclear Weapons Protest in America* (Newbury Park, Calif.: Sage Publications, 1989).

[100] Ibid., 35-36.

Since theorists such as McCrea and Markle believe, following Marx, that class struggle is tied to irresistible world-historical forces arising from the evolution of capitalism, it becomes difficult to use their theory of social movements to explain how *real, discrete* events -- like technological disasters -- could contribute substantively to shifts in the balance of political power. As I hope to show, disaster events are not simply "resources" for the mobilization of protest groups, nor are they reducible to the vague "precipitating factors" or "critical events" to which social movement theorists resort when it begins to seem that their explanations are devoid of anything that moves.[101]

A disaster, rather, provides a flood of news about a technological system's technical and political structure, and this news sometimes convinces a sector of the public that the system needs fixing or replacing. Social movements may arise as a result, but their goals are usually well-defined, centering on preventing the construction or operation of particular industrial facilities. Collectively, these groups can slow or stop an entire industry -- as we will see in the next chapter -- but this is not the driving agenda of each local group. Members are usually concerned about their own safety and health and about exercising their rights to participate in political and technological decisions. They are not simply acting out hidden class envies;

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[101] This critique does not apply to Alain Touraine's "critical action theory," which takes a much more historicist approach to the development of social movements. Touraine argues, for example, that "At the origin of the anti-nuclear struggle are to be found on the one hand the fear of the harmful effects of radiation in the factories and on the environment...and on the other hand an appeal to the natural life with an increasingly strong rejection of an industrial civilization which depletes resources, pollutes, overcrowds and fatigues human beings and sinks into contradiction and absurdity...A social movement is taking shape...[that] no longer opposes workers and bosses but the great apparatuses which determine their way of life and their collective future, which impose their decisions on the whole of the community in the name of technical rationality and economic necessity." In Touraine, et al., *Anti-Nuclear Protest: The Opposition to Nuclear Energy in France,* Peter Fawcett, trans. (Cambridge, U.K.: Cambridge University Press, 1983) 174, 179.

many are not sufficiently educated or cosmopolitan to be considered part of the "New Class." It has been said that God (or the Devil) is in the details. This is true for anti-technology movements as well. Once people have learned the details of a technological disaster, these details become the substance of new knowledge-based conflicts over objective hazards and the political mechanisms by which these hazards have been apportioned.

The web of local movements expressing a growing grassroots skepticism toward technological "progress" is most commonly known by the acronym NIMBY, for Not In My Back Yard. Initially a derogatory banner invented by critics, the label has come to be used by scholars and even, with perverse pride, by members of the movements themselves to refer to local opposition to the siting of hazardous or undesirable technological projects in the locales where the protesters live or work. Journalist Charles Piller's conversion on this issue in *The Fail-Safe Society* illustrates the way the word's meaning has evolved:

> Conventional wisdom, as promoted by those who introduce, manage, or profit from science and technology, holds that NIMBYism is the product of selfish ignorance about risk and that NIMBY groups should be stamped out before they irreparably harm our ability to extend society's technical reach and our standard of living. When I began this book, in a basic way I agreed with this view. I saw NIMBYism as a vexing problem to be solved...[but] as I examined the roots of the NIMBY phenomenon...I grew to recognize that by labeling NIMBYism as the problem I had obscured more central issues. It is not risk per se, but how hazards have been generated and distributed that has led to the NIMBY era.[102]

While certainly opposed to specific technologies as they have been implemented, NIMBY groups are not necessarily anti-technocratic, much less revolutionary, in nature.[103] They do not aim to overthrow the "ruling class."

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[102] Charles Piller, *The Fail-Safe Society: Community Defiance and the End of American Technological Optimism* (Berkeley, Calif.: University of California Press, 1991) 14.

[103] I have portrayed the concept of "risk" as part of technocrats' attempt to recapture technological control from the NIMBY movements that threaten to erode it. To the extent that they must combat "riskism," therefore, NIMBY movements may be anti-technocratic.

In fact, their members are often political conservatives (as, for example, in the rural regions of southeastern Pennsylvania where many residents became anti-nuclear protestors after Three Mile Island) who simply dislike the way decisions about important technological developments are made. They are usually respectful of the power of science and scientists to better the human condition, and in many cases they have called on sympathetic scientists and technicians for assistance in their campaigns. Most of these groups are *for* local control -- community involvement in decisions about current and future technologies -- and *against* the rule of large-scale technological systems, especially with regard to the siting and operation of facilities that could one day break down catastrophically.

Other NIMBY groups, of course, are obstructionist: witness, for example, the vehement opposition in many communities to the construction of drug-treatment centers or group homes for the mentally ill. It should be recognized, however, that the popular vetoes often mobilized by NIMBY movements are one of the few tools citizens can use to affect technological politics. "Our strategy is basically like plugging up the toilet," says Lois Gibbs of the Citizens' Clearinghouse for Hazardous Waste. "By stopping [industry] from opening new landfills, incinerators, and hazardous waste sites, what happens? When the cost is high enough, corporations will decide to recycle wastes and reclaim materials, to substitute nontoxics in their products, to change their processes of production."[104] In this way, citizens' power to *prevent* may gradually be transformed into the power to *change* and *create.*

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[104] Quoted in Greider, 169-170. The monthly newsletter of the Clearinghouse is entitled *Everyone's Back Yard.*

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This chapter has had a number of goals: to draw a distinction between large-scale technological disasters and other kinds of catastrophes; to trace the history of, and some of the flaws in, the idea of cybernetic control; to explore large technological systems' role in governing society; to emphasize the political importance of breakdowns in these systems; and to distinguish these ideas from other thinking on the social meaning of technological hazards. In the coming chapters I will use this framework to explore my basic claim that control breakdowns in large technological systems disclose the hidden technical and political nature of these systems, creating valuable leeway for democratic experimentation in technological societies.

The results of these experiments are often subtle, tentative, and incomplete. I do not intend to argue that technological disasters automatically bring societies closer to Jeffersonian democracy, or that, as one wit put it after Three Mile Island, "every radioactive cloud has a silver lining."[105] The main insight in the following case studies, rather, is that technological catastrophes generate broader understanding of both the *technical flaws* and *political implications* of large systems. What citizens actually do with this new understanding, and whether they can use it to win greater safety and greater control over technology, depends on their own skills, motivations, and political strengths and on the power and resilience of their opponents.

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[105] Quoted in Richard D. Lyons, "Nuclear Plant Shutdown: Possible Blessing," *The New York Times* (April 11, 1979) A18.

Chapter 2

THE PRECIOUS DARK

The New York City Blackouts of 1965 and 1977

Here come more stars to character the skies
And they in the estimation of the wise
Are more divine than any bulb or arc,
Because their purpose is to flash and spark,
But not to take away the precious dark.
We need the interruption of the night
To ease attention off when overtight,
To break our logic in too long a flight,
And ask us if our premises are right.

— from Robert Frost, "The
Literate Farmer and
the Planet Venus"[1]

The bigger a technology grows, the less noticeable it becomes. Probably the most remote and invisible parts of our technological environment, because they envelop us so completely, are the large, distributed systems described in Chapter 1. We do things *with* these systems, but we seldom contemplate doing anything *about* them, since as long as they are functioning normally they remain hidden, unobtrusive, and quite impervious to local inputs. As historians of technology Donald MacKenzie and Judy Wacjman have written, "We live our lives in a world of things that people have made. Mostly we take that world for granted. We do not ask why our refrigerator makes an annoying humming noise, nor why our domestic appliances are shaped the way they are. We think about electricity only when the bill has to be paid, or when the supply fails...Technological change seems to have its own logic, which we may perhaps protest or even try to block, but which we appear to be unable to alter fundamentally."[2]

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[1] From "The Literate Farmer and the Planet Venus," *The Poetry of Robert Frost* (New York: Holt, Rinehart, and Winston, 1969) 368-370.

[2] Donald Mackenzie and Judy Wacjman, eds., *The Social Shaping of Technology: How the Refrigerator Got its Hum* (Philadelphia: Open University Press, 1985) 2.

Electrical power networks are the most forgettable and far-removed of large systems, yet they underpin all our activities.[3] Thomas Edison installed the world's first commercial power network in Manhattan in 1882, less than two human lifetimes ago; today the generation of electricity consumes one-third of the energy used in the United States, more than any other sector.[4] Even this figure understates electricity's importance, since nearly every phase of modern manufacturing, transportation, communication, and business administration depends on its steady supply. Demand for electricity in the United States increased by a factor of almost 100 between 1900 and 1950.[5] It then doubled between 1950 and 1960, doubled again between 1960 and 1970, and doubled yet again between 1970 and 1990.[6]

More subtly, however, electrical devices have infiltrated every part of daily life. The alarm clock that wakes me in the morning, my coffeemaker and toaster and shaver, the computer on my desk are all electrical. (Simply programming all desktop computers in the U.S. to go into electronic hibernation when they are not being used, according to the Environmental Protection Agency, would save an amount of energy equivalent to the annual electricity use of Vermont, New Hampshire, and Maine combined.[7]) The nation's electrical utilities, for their part, are straightforward about the nation's increasing dependence on electricity, even proud of it. "Electricity as an agent of technological progress has left as strong an imprint on our daily lives at home as on the performance of work in the industrial sector," boasts the Electric Power Research Institute, an industry think tank and lobbying organization. "Further, no end is in sight, given the rapid proliferation of electronic, mechanical, and thermal applications of electricity in the home."[8]

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[3] And the first studied in detail; see Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983).

[4] Pietro S. Nivola, *The Politics of Energy Conservation* (Washington, D.C.: The Brookings Institution, 1986) 151.

[5] Sam H. Schurr and Bruce C. Netschert, *Energy in the American Economy, 1850-1975* (Baltimore: Johns Hopkins Press for Resources for the Future, Inc., 1960) 181.

[6] Growth slacked off somewhat after the Arab oil embargo of 1973. Sam H. Schurr, et al., *Electricity in the American Economy: Agent of Technological Progress* (New York: Greenwood Press for the Electric Power Research Institute, 1990) 382.

[7] Steve Lohr, "Recycling Answer Sought for Computer Junk," *The New York Times* (April 14, 1993) A1, D13.

Electrification has even shaped the way we think about how large enterprises should be managed. The vesting of control over electrical generation and distribution in private investor-owned utility companies has long been a simple "fact of life" within the industrial economy of the United States.[9] "Almost from its earliest days, the physical and economic characteristics of the electrical industry were recognized as such that a single supplier within a local area offered the most efficient way of getting electric power generated and delivered to the consumer...Furthermore, each supplier needed to stand ready to meet the peak demands of all its customers in a situation in which production and consumption occur simultaneously... [leading to] spontaneous merger of the separate systems that were originally in existence within many localities."[10] Very early in the industry's history, the special logic of efficiency closed off the possibility of local control over the supply of electricity, guaranteeing the growth of what are politely called "natural monopolies."

In a very brief time, in other words, the electrification of modern society by centralized, large-scale energy bureaucracies has become a *tradition*, in the sense of an inherited, established, or customary pattern of thought, action, or behavior.[11] (This is one of the fascinating ironies of modern technological development: that it establishes itself as permanent and inevitable while simultaneously bringing unceasing upheaval and change. It attempts to displace all other traditions with its own.) And traditions, while they are our main link to the past and the source of the cultural continuity that makes life comprehensible, can also work to make the present seem inevitable and unremarkable. They discourage us from asking why things are the way they are. Martin Heidegger, the German philosopher, had this to say about tradition:

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[8] Schurr, et al., 269.

[9] Hans H. Landsberg and Sam H. Schurr, *Energy in the United States: Sources, Uses, and Policy Issues* (New York: Random House, 1968) 209

[10] Ibid.

> When tradition thus becomes master, it does so in such a way that what it "transmits" is made so inaccessible...that it rather becomes concealed. Tradition takes what has come down to us and delivers it over to self-evidence; it blocks our access to those primordial "sources" from which the categories and concepts handed down to us have been in part genuinely drawn. Indeed it makes us forget that they have had such an origin, and makes us suppose that the necessity of going back to these sources is something which we need not even understand.[12]

Electricity is among the most fundamental "categories and concepts" handed down to us by the Second Industrial Revolution. It has, as the electrical industry claims, "penetrated deeply and brought important changes into virtually every corner of American life," so much so that we are seldom conscious of the extent of our dependence on it or of the complex political and technical arrangements by which it is delivered to us.[13] We only know that when we flip a switch, the lights come on. Beyond this point, the technicians are in charge.

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[11] This is one definition offered by Webster's Ninth New Collegiate Dictionary. Another relevant definition might be "characteristic manner, method, or style," since reliance on large technological systems such as electrical grids is a part of the established "technological style" of modern industrial societies.

[12] Martin Heidegger, *Being and Time*, translated by John Macquarrie & Edward Robinson (San Francisco: Harper & Row, Publishers, 1962) 43.

[13] Schurr, et al., xiii.

But must it be this way? Must we depend for this basic resource on a system that is so complex, inaccessible, and monolithic? Must we get our electricity from big utility companies and giant generating stations whose capacities vastly outscale the end uses to which the power is put? Must we trust that this system is the safest and most reliable that can be built? And must all future growth in electricity demand be met using the same approach? In short, is there any reason to respect the century-long tradition of centralized electric power distribution in the United States, other than that it is such a tradition?

Though Heidegger seems to have considered the quest for human control over technology ultimately futile[14], he did offer a possible antidote to technology-as-tradition in his landmark study *Being and Time*. Heidegger's main concern as a philosopher was with the nature of existence, or what it means to "be" in the world. But in order to pin down the nature of being-in-the-world, he had first to say what that world is. In Heidegger's scheme the world is constituted by the sum of the entities which we encounter and use in our everyday lives: in other words, tools. (His precise word was *Zeug*, which can also mean "gear," "equipment," or just "stuff".) Tools, according to Heidegger, can either be "ready-to-hand," existing only to be used, or "present-at-hand," existing as objects of attention in themselves. On the surface this distinction might seem academic. It rests, after all, more on the way we *perceive* objects than on their "real" essences. But for exactly this reason, it helps us to reflect more carefully on the ways in which we take certain artificial parts of our environment wholly for granted.

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[14] See Langdon Winner's discussion of Heidegger in *Autonomous Technology: Technics-Out-of-Control as a Theme in Political Thought* Cambridge, Mass.: MIT Press, 1977) 131.

Heidegger believed that people deal with tools primarily as ready-to-hand, that is, without really thinking about their roles or "assignments." Thus a hammer typically exists as such only while being used in the act of hammering. But here is the important point: For Heidegger the hammer's presence-at-hand, its meaning as an object separate from its user, *becomes most visible when it is damaged, missing, or unusable,* and therefore conspicuous. "When an assignment has been disturbed -- when something is unusable for some purpose -- then the assignment becomes explicit," he wrote. "The context of equipment is lit up...Similarly, when something ready-to-hand is found missing, though its everyday presence has been so obvious that we have never taken any notice of it, this makes a break in those referential contexts which circumspection discovers. Our circumspection comes up against emptiness, and now sees for the first time...what the missing article was ready-to-hand *for*."[15]

A hammer is a considerably simpler tool than an electrical generation and transmission network, but Heidegger's point can be generalized. People do not fully comprehend what their machines are doing for them, or *to* them, until those machines malfunction. The machines then cease to exist merely as extensions of their designers' or users' intentions; they become autonomous objects, impinging on the world with their own recognizable set of requirements and effects. A system breakdown of the kind described in Chapter 1 is, in Heidegger's terms, the ultimate "assignment disturbance." With the loss of control in a complex technological system, the functions of the various subsystems begin to conflict. They may either cancel each other out or resonate catastrophically. If the conflict is bad enough, the system finally shatters into all its constituent purposes, and the figurative debris is thrown about for everyone to see. Attentive citizens taking up the role of "technopathologist" may use this evidence to argue for a reevaulation of existing methods of planning and control.

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[15] Heidegger, *Being and Time,* 105.

MacKenzie and Wacjman's observation that "we think about electricity only...when the supply fails" is thus a weightier one than they may have realized. For reasons we began to explore in Chapter 1, large technological systems like electrical grids do not always function as designed. Even if all of a system's constituent parts are well understood and perform according to specifications, the system as a whole can still collapse in response to unexpected blows from without or unexpected conflicts from within. The electrical power industry has suffered its share of system breakdowns in this century, and the few that were bad enough to be memorable -- notably, the great Northeast power failure of 1965 and the New York City blackout of 1977 -- were classic examples of the "brittleness" of large, complex, tightly-coupled technological systems.[16]

But they were also, as Winner put it, "opportunities to inquire, to learn, and to seek something better." The present chapter is included in this study of the political meanings of technological disasters not because the blackouts generated a widespread grassroots response -- they did not -- but because they contributed to a slowly gathering critique of the way electricity is generated and distributed in North America. This critique, together with long-term economic trends affecting the growth of electrical demand, is beginning to result today in significant technological and political changes for the industry. The 1965 and 1977 blackouts forced citizens to recognize that with dependence comes vulnerability: that the comfort provided by our electrified surroundings masks our enslavement to the possibility of system-wide failure. Seeing how the "interruption of the night" can "break our logic in too long a flight," therefore, means interpreting an event like a blackout as something more than an inconvenience.

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[16] See Amory B. Lovins and L. Hunter Lovins, *Brittle Power: Energy Strategy for National Security* (Andover, Mass.: Brick House Publishing Company, 1982).

The Great Northeast Power Failure

It was the middle of rush hour in New York City on a crisp November afternoon in 1965. The vast living machine made up of subways and elevators and stoplights and computers and over seven million people -- the most complex technological setting on Earth -- pulsed with traffic and vitality. Then without warning, at half past five, the machine stumbled and lurched into a comatose silence from which it would not completely reawaken until thirteen hours later. For the first time in its history, New York had succumbed to a complete failure of its electrical power network.

Hundreds of thousands were trapped in darkened subway tunnels and elevator shafts. In hospitals, surgeons hurriedly finished their operations by candlelight. Airline pilots watched in horror as runway lights at LaGuardia and Kennedy airports flickered, then went out. It would have been like a scene from the 1951 science-fiction film *The Day the Earth Stood Still*, except that the city's cars, trucks, and taxis, equipped with their own generators, still crawled through the nearly-paralyzed streets, casting meager illumination from their headlights. Overhead, luckily, there was a full moon. For once uncontested by the city lights, its brightness reminded some of the "bomber's moon" that hung over London during the Blitz.

New Yorkers were not alone in the crisis, though they discovered this only slowly as they listened to news updates over their battery-powered transistor radios. Incredibly, the power failure blanketed all of New York State, Connecticut, Massachusetts, Vermont, New Hampshire, parts of Maine, and the southern chunk of Ontario. These areas were home to over 30 million people, more than had been affected by any other blackout in history. For most, power was restored within two to eight hours. But the unforeseen necessity of "cold-starting" a distribution system as complex as New York City's delayed Consolidated Edison's efforts to restore power fully until early the next morning. For the millions of New Yorkers who lived through this "eerie all-night fantasy when the whole machinery of life came to a halt," to use the words of one reporter, a resource normally taken for granted gained sudden conspicuousness through its very absence, just as Heidegger had predicted.[17]

New York's blackout experience was all the more remarkable in view of the city's role as the birthplace of commercial electric power. Consolidated Edison (Con Ed), the city's sole supplier of electricity for heat, light, and power, is a descendent of Manhattan's Edison Electrical Illuminating Company, which acquired the world's first electric lighting franchise from the city government in 1881. The six direct-current generators located at the company's first station on Pearl Street had originally been designed by Thomas Edison to supply power to 1,200 sixteen-candlepower lamps. The innovation proved an immediate success, and Edison's base of 59 customers expanded to over 500 within the first year of service, with 11,000 lamps lit by the end of 1883. To avoid adding to the mess of overhead telephone and telegraph wires already clogging the city's skyline, Edison inventively placed electrical lines underground in iron conduits. Soon franchises began springing up to serve other parts of the city, and they offered electricity for *power*, not just light. The city's gas distributors, rightly worried about these new developments, merged into the Consolidated Gas Company in 1884 and began, in 1901, to acquire the electrical franchises serving Westchester County and all of New York's five boroughs, including the original Edison Electrical Illuminating Company. In 1936 the Consolidated Gas Company changed its name to the Consolidated Edison Company.[18]

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[17] Homer Bigart, "A Night of Confusion, Frustration, and Adventure," *The New York Times* (Nov. 11, 1965) 1, 37.

By 1965, Con Ed represented only one small region in a nationwide electrical web with a total annual output of a trillion kilowatt-hours -- more than Britain, France, Germany, Japan, and the Soviet Union combined. Electric power consumption in the U.S. that year was triple what it had been in 1950. The electrification of even the most remote areas under the New Deal's Rural Electrification Administration was essentially complete, with privately-held utility companies serving about eighty percent of the nation's electrical customers and publicly-owned cooperatives and government agencies serving the rest. The national electrical grid connected hundreds of local and regional utilities into six major groups, the largest of which, the Interconnected Systems Group, stretched from Canada to the Gulf of Mexico and from the Atlantic coast to the Rocky Mountains. Con Ed was part of this group.

Part of the logic behind the grid system was that it improved reliability: a company whose own generating capacity was reduced for some reason could maintain service by importing power from outside sources. But the utilities had not linked arms for purely altruistic reasons. The grid evolved during the nineteen-forties and fifties as a way for utilities to ensure continual expansion by keeping the cost of electricity down. Instead of duplicating each others' efforts to build generating capacity, the companies agreed to share power by transmitting it over long distances to the locations where it was needed most at any given time. High electrical demand during the 5:00 p.m. rush hour in New York City, for example, might be met using excess generating capacity in rural areas as far away as Michigan, where the daily demand curve corresponded to farming routines. In this way individual utilities could obtain power from the most cost-efficient sources and also reduce the reserve capacity they set aside for maintenance, repairs, and emergencies. The strategy seemed to work. While the cost of living in the United States doubled between 1940 and 1965, the inflation-adjusted cost of electricity fell by half.[19]

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[18] Lurkis, Alexander, *The Power Brink: Con Edison, A Centennial of Electricity* (New York, The Icare Press, 1982) 16-44.

Con Ed, with its 91 boilers supplying steam to 68 turbine-generators at 12 generating stations (one of them nuclear, many of the rest recently converted from sulfur-dioxide-emitting coal to oil), 45 major substations plus 215 unit substations, 60 miles of underground cable carrying power at 345,000 volts, 300 miles carrying 138,000 volts, and 42 network areas supplied by more than 700 network feeder cables, was the most complex generating, transmission and distribution system in the world. It was also the largest utility in a confederation of 42 power companies called CANUSE, for Canada-U.S.-Eastern. The region's main 345,000-volt transmission lines formed a giant **T**, with one line running east-west from Detroit to Boston via Niagara Falls, and the other running north-south from Schenectady to New York City. (See Figure 2.1.) Like Venice and Stockholm, New York City is an archipelago, cut off from the mainland by the Hudson and East Rivers and Long Island Sound. Because it is difficult to lay power cables either over or under the water, the city's power connections to the outside world have always been somewhat precarious. But with links to New Jersey and upstate New York -- and, through them, to the entire CANUSE grid -- Con Ed power planners in 1965 did not believe they would ever face a total shutdown, no matter how much local generating capacity was temporarily lost. The system was designed to compensate immediately by rerouting the flow of electricity from far-away generating stations.

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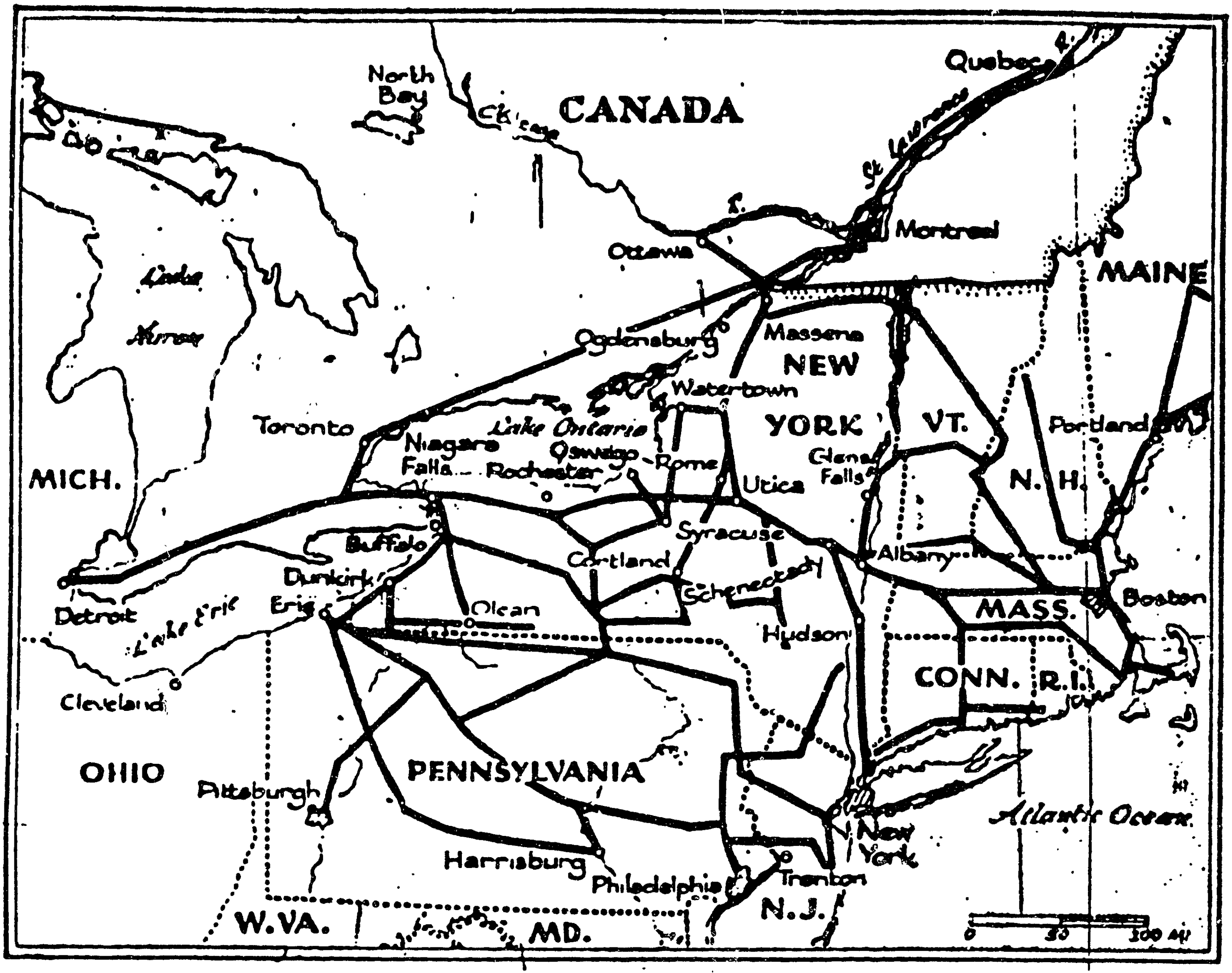
[19] A.M. Rosenthal and Arthur Gelb, eds., *The Night the Lights Went Out* (New York: Signet, 1965) 68-76.

But there was a catch. In pooling their power resources to prevent local brownouts and blackouts without also equipping themselves with centralized control facilities and displays of the grid's condition, the utilities had unwittingly opened themselves to system-wide failure. By its very architecture, the grid as it stood in the early nineteen-sixties -- before the technical lessons of the great Northeastern blackout -- was just as capable of communicating a massive power drain to all its member utilities as it was of occasionally shoring them up. The danger was that a severe breakdown in one section of the grid would create an excessive drain on neighboring utilities, which might collapse and drag down *their* neighbors in turn -- a cascading effect that the automatic circuit breakers on some transmission lines might not prevent. Moreover, the interconnection of separate utilities meant that the 60-Hertz cycle of the alternating current being generated at hundreds of power stations around the grid had to be exactly synchronized. Power drains often caused a drop in this frequency, and even small discrepancies could lead generators to "quarrel" and cut off automatically.

Such were the possibilities on the eve of the November blackout. Con Ed officials, however, were sanguine. "In the push for improved efficiency in generation and transmission in the nineteen-fifties and early nineteen-sixties,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Behind the Light Switch Lies Complex
Power Network Covering Entire Northeast

Fig. 2.1: Principal Power Connections in Canada-U.S.-Eastern Confederation (Source: The New York Times, Nov. 15, 1965, p, 42.)

reliability was nudged aside and relegated to a somewhat lesser role," Michehl Gent, current president of the North American Electric Reliability Council, explains today.[20] This is not to say that Con Ed engineers underestimated the amount of disruption a city-wide blackout would cause; even 34 years earlier a proposal to turn off the city's electric current for a single minute in honor of the death of Thomas Edison had been rejected as too costly and dangerous.

But Con Ed *had* failed to read the warning signs provided by earlier power failures. A blackout that prefigured the 1965 disaster in miniature occurred on August 17, 1959, when five square miles of upper Manhattan lost power for more than twelve hours. The chief engineer for the city's Bureau of Gas and Electricity, Alexander Lurkis, blasted Con Ed for having failed to provide sufficient electric feeder capacity to the affected areas. Lurkis wrote in his official report that the pre-existing overload, combined with the company's inability to isolate faulty sections from the rest of the urban grid, had resulted in a cascading series of feeder breakdowns. Con Ed, however, denied that its grid was at fault, calling the failure an "act of God." The company went on to state that "the mathematical chances are negligible that a similar situation will develop again." But a nearly identical breakdown "developed" less than two years later, on June 13, 1961. This time, five square miles of mid-Manhattan were paralyzed for more than four hours by the failure of a high-voltage circuit breaker at one substation and the consequent shutdown of two other substations. Not until the early nineteen-seventies, after the massive 1965 blackout, did Con Ed give in to public frustration over these frequent breakdowns and begin to study changes in its underground distribution system.[21]

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[20] *North American Electric Reliability Council 1990 Annual Report*, 4.

[21] Lurkis, *The Power Brink*, 1, 51-55.

Relay Race

The utility's inability to protect itself from cascading power shutdowns was precisely what made the big 1965 blackout possible. The failure began -- as most technological failures do -- as a combination of human unmindfulness and minor electromechanical failure. A shoebox-sized transmission relay at the Ontario Hydro-Electric Power Commission's Sir Adam Beck generating station in Queenston, Ontario, had been set in 1963 to interrupt the westbound flow of power if the load on its line exceeded 375,000 volts. That line, however, was capable of transmitting 500,000 volts, and controllers, unaware of the low setting on the relay, had been using it to transmit higher and higher voltages to meet growing demand in Toronto. At eleven seconds after 5:16 p.m. on November 9, 1965, they finally pushed the relay too far. Load on the line briefly climbed above 375,000 volts, and the relay tripped circuit breakers that took the line out of service.

Electricity is the flow of electrons and can be compared to water flowing downhill through a sluice gate. Electrical current, measured in amps, corresponds to the volume of water passing through the gate per unit time, and the potential difference between the electrons' source and their destination, measured in volts, corresponds to the height from which the water falls. But the crucial part of the analogy here is that as long as circuits are closed and there is a positively-charged destination to draw on the negatively-charged electrons, then electricity, like water falling under the force of gravity, *will take any available route* to its destination. When the first line to Toronto tripped out, its load was thrown onto four parallel lines, all of which overloaded and disconnected within three seconds. Now the big block of power being generated at the Beck plant tried to reach Toronto by way of lines through upstate New York. Those lines overloaded and failed as well, forcing the Beck plant off-line.

With major transmission lines out of service, electrical demand in the Lake Ontario region would now have to be met by generating stations in other parts of the CANUSE grid. To protect itself, the Pennsylvania-New Jersy-Maryland part of the eastern grid cut off all connections with CANUSE. The Con Ed system, which had been importing 220,000 kilowatts moments before, suddenly found itself confronting a massive power drain to the north. Demand exceeded supply by 1.1 million kilowatts. Generating stations throughout New York and New England strained to make up the gap, but when two New England generators quarrelled and tripped off, the Eastern grid began to fracture into all its constituent parts. Rapid frequency declines caused more generators to go off-line. In the New York City control room, Con Ed engineers tried frantically to "shed load" by closing relays and cutting off power to individual neighborhoods, including the West Bronx, Yorkville, and East Brooklyn. But they were too slow. At 5:28 p.m., twelve minutes after the first relay tripped at the Ontario station, the entire Con Ed system collapsed, along with most of New England, New York State, and Ontario.[22]

The Blackout Experience

The city quickly ground to a halt. And so, save for their automobiles, telephones, and transistor radios, New Yorkers found their technological habitat completely inert: proof of how thoroughly the built environment had been shaped around the availability of electricity. Water pressure to the upper floors of high-rise building dropped to zero. Gasoline stations could no longer pump gas. All of New York's nine television stations were forced off the air. Not even during the jittery time of air-raid drills during the second World War had the city been this dark. New York-based *Time* magazine wrote:

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[22] Dorothy Ellison and Kathleen R. Gordon, special section on the 10th anniversary of the blackout, *Around the System* (Consolidated Edison newsletter) (October, 1975) 16-17.

> New Yorkers assailed by the chill night -- and, for a frozen instant, silence -- reacted almost sportively, as if it were all a gigantic game of Blind Man's Buff [sic]. In soaring office buildings and fetid subway tunnels, beleaguered commuter trains and jampacked terminals, they joked and chattered, waiting from minute to minute for the reviving whine of dynamos, the first stutter of returning light. And, incredulously, they began to realize at last that they had been transported to Caliban's world, a vast, trackless cave without warmth or wheels, without hot food or the lights of home.[23]

The events of that long night would become a kind of urban legend. Everyone who took part had a story to tell afterwards, sometimes even decades later. The blackout, ironically, caused what sociologists have called the "flashbulb effect," illuminating the oft-forgotten details of daily existence in an unfamiliar fashion and freezing the experience in people's memories. "This is the type of day where you remember everything. Everything you did, everything you ate. I'll remember it all," a young woman told *The New York Times*. She was eating lukewarm frankfurters and cold baked beans by the light of a flickering candle in a Lexington Avenue luncheonette. One utility employee would write ten years later, "It was one of those timesheds, like Hurricane Hazel and the Kennedy assassination, around which people relate the events of their lives."[24]

To the contemporary imagination, sobered by the violence and urban decay of the intervening decades, certain events of that night would seem unbelievable if not for the direct historical evidence confirming them. Crime, for example, was virtually absent: there were only one-quarter as many arrests as on a usual night. Only three people died as a result of the blackout. One fell down a stairway and struck his head, another had a heart attack after climbing ten flights of stairs, and a third was found at the bottom of an elevator shaft six days later. (No one knew how he had gotten there.)

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[23] "The Disaster That Wasn't", *Time* (November 19, 1965) 20-25.

[24] Rosenthal, *The Night the Lights Went Out*, 47; Jim Dunn, "Ten years later and all's well," *Hydroscope* (Newsletter of the Ontario Hydro-Electric Power Commission) (Nov. 7, 1975).

Perhaps even more astonishing, however, the blackout brought out a streak of humanity and carefree generosity in New Yorkers that surprised even themselves. "New Yorkers learned something about themselves yesterday that they probably never suspected," wrote one journalist. "Under stress, and in the face of the unknown, they proved, generally, to be courteous, friendly, and considerate." Another reporter observed that normally defensive urbanites "helped one another, gave one another rides home, lent each other matches and cigarettes and candles. In many apartment buildings, children with candles stood ready to lead tenants up the pitch-black stairs." One woman received so many courtesies during the power failure that she said it had "restored her faith in mankind." A magazine commentator marveled, "The blackout showed that when the switches are down, New Yorkers have a heart; are human, after all; and can display a sense of humor." When a fireman who had broken through the wall of a stalled elevator in the Empire State Building asked whether there were any pregnant women in the car, one of the men trapped there reportedly replied, "We've hardly even met!"[25]

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[25] Richard J.H. Johnston, "Bright Side to Blackout: Hidden Virtues Show Up as New Yorkers Give Help During Crisis," *The New York Times* (Nov. 10, 1965) 4; *The Night the Lights Went Out*, 46; Howard Simons, "Inquest on Power," *The New Scientist* (Nov. 25, 1965) 569; McCandlish Phillips, "Blackout Vignettes Are Everywhere You Look," *The New York Times* (November 11, 1965) 37.

Chief Engineer Lurkis was himself one of the 800,000 people stranded in the city's subway tunnels and bridges. He described his fellow citizens' aplomb this way:

> Traction power was lost just as my train entered the Brooklyn-New York under river tunnel on the Brooklyn side. The passengers were marvelous in their calm...Someone had a transistor radio, and that is how we found out it was a blackout. When it was reported that the traffic signals and street lights were out, and that traffic was jamming everywhere, I decided to stay put where there was some light, rather than fight the traffic, the cold weather and the uncertain conditions in the open. Four hours later, when the train's battery lights started to dim, I decided it was time for me to move. I walked to the rear of the train, with the aid of a trainman's lantern and along to track to the Brooklyn station. I climbed out of the station, and after waiting for some time, grabbed a bus running over the Manhattan bridge...The walk through the darkness to the west side was without event; no molestation or mugging. The people along the way took the disaster with good humor, enjoying the unusual experience...Drivers used extreme caution and courtesy in driving through the dark streets aided by volunteer traffic directors.[26]

Millions shared this unexpected serenity in the face of the disaster. A lawyer working with his colleagues on the 32nd floor of a Third Avenue office building, reluctant to walk the 600 darkened steps down to the street, told a reporter, "First we just sat around having drinks. Now we're having a seance to communicate with the spirit that caused this bliss...We're all getting to know each other."[27] A man who was in an all-night bar when the power came back on remarked, "You know, it's a big pain and all, but I sort of hate to see it all over. Tomorrow will be just another working day."[28]

Counter to the widely-held perception that natural and technological disasters are nightmarish ordeals, researchers say the experience of disaster often involves a strange and infectious kind of euphoria. David Riesman, the Harvard sociologist whose 1950 study of post-industrial autonomy and conformity among Americans, *The Lonely Crowd,* had become a bestseller, gave this explanation for behavior during the blackout: "When something like this happens, it's not our fault and we know it's not. So we say to ourselves, 'Fate is in charge,' and we enter into an era of good feeling. That's what happened Tuesday night."[29] But the psychic roots of the spontaneous cameraderie and goodwill demonstrated by New Yorkers during the 1965 blackout may go deeper than Riesman suggested. Michael Barkun, author of an extensive study on millennial cults, has written that "Mass ecstasy -- or, to use the terminology of historians of religion, *enthusiasm* -- stems from two principal causes: radical changes in sensory stimulation and situations which create extraordinary degrees of tension and anxiety...Disaster inadvertently produces many of the same effects as intentional ecstatic techniques."[30] Both of Barkun's ingredients were present in the blackout, and mass enthusiasm, if not quite "ecstasy," seems an apt description for New Yorkers' reactions that night.

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[26] Lurkis, *The Power Brink,* 56-57.

[27] William Borders, "Many Caught in Elevators, Most Quickly Freed — Upper Floors Soon Become Jovial," *The New York Times* (Nov. 10, 1965) 3.

[28] Homer Bigart, "A Night of Confusion, Frustration and Adventure," *The New York Times* (Nov. 11, 1965) 1, 37.

Certainly, the blustery joviality displayed by many was partly a cover for deeper worries and anxieties -- for example, that the Russians might somehow be responsible for the disaster, or simply that they might not reach their homes until very late that evening. And for what *New York Times* editor A.M. Rosenthal called "the plugged-in society," the loss of power and light did amount to a radical change in sensory stimulation. It was not a change New Yorkers would have endured voluntarily; historian David E. Nye has described how, even as early as World War I, emergency cutbacks of the dramatic electric lighting so characteristic of New York City had proved an

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[29] "The Disaster That Wasn't," 25. See also David Riesman, *The Lonely Crowd: A Study of the Changing American Character* (New Haven: Yale University Press, 1950, 1965).

[30] Michael Barkun, *Disaster and the Millennium* (New Haven: Yale University Press, 1974) 156-57.

"unacceptable psychic loss" for its residents.[31] But the disruption did provoke people to a heightened awareness of their physical and social surroundings, one of those rare moments when the familiar suddenly seems strange and wonderful. As an awed Columbia University student stuck on the 86th-floor observatory of the Empire State Building remarked, "You should see the full moon shimmering in the East River -- I've never seen anything like it!"[32] With its darkened towers silhouetted against the moonlit sky, its televisions and hi-fis silenced, the technological metropolis became a huge canvas for the human imagination. It was all oddly exciting. "While the city of bricks and mortar was dead," the editors of *The New Yorker* wrote, "the people were more alive than ever."[33]

Escaping the "Prison Farm of Modern Technology"

Aside from the darkness, the most obvious part of the radically altered environment -- and, judging from New Yorkers' own statements, a surprising source of "disaster euphoria" during the blackout -- was the fact that *nothing electrical worked anymore.* "To Americans served and shielded by machines at every turn, each silent switch and powerless push button was a taunt," *Time* magazine observed. "Yet Northeasterners wasted little time lamenting their betrayal by the machine. Instead, with a high sense of shared adventure, they set about the unfamiliar task of using legs and arms to help themselves and their fellow men." Many took advantage of the opportunity to try out long-disused skills and to resurrect technologies from simpler days. Candles were at a premium that night. (The news staff of the *New York Times*, the only newspaper to publish the day after the blackout, worked through the night under the glow of ceremonial candles from Holy Cross and St. Malachy's Roman Catholic churches and elegant restaurant candles from the Astor and New Yorker hotels.[34]) Thousands, like Chief Engineer Lurkis, cheerfully walked miles to reach their homes. People everywhere made do with what they had, and seemed to enjoy it. *Time* reported, "When power failed in the $37,500 Queens home of Mechanical Engineer Edwin Robbins, the result was pure farce. Nothing worked, not the multitone door chimes or the intercom system, not the Danish dining-room chandelier or the bedroom clocks, not the hair dryer or the electric blankets, not the can opener or the carving knife, not the toothbrush or the razor. Not even the electric-eye garage door. For dinner, the Robbins had charcoal-broiled steaks grilled over a primitive backyard barbecue."[35]

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[31] The U.S. Fuel Administration had ordered the city's electric signs turned off as a conservation measure, and "Broadway had been dark only two or three nights before requests that the lights be turned on again began to pour into the headquarters of the Fuel Administration...The advertising signs were soon turned on again so that the city could appear 'normal.' " David E. Nye, *Electrifying America: Social Meanings of a New Technology* (MIT Press, 1990) 60.

[32] Borders, "Many Caught," 3.

[33] Quoted by Lewis Mumford, *The Myth of the Machine: The Pentagon of Power* (New York: Harcourt, Brace, Jovanovich, 1964, 1970) 409.

The *Times*, understandably prideful for having defied the blackout by publishing an abbreviated morning edition at the plant of a New Jersey newspaper, editorialized that "Suddenly, man's capacity to send rockets to the moon, to produce limitless quantities of goods without human effort, faded into irrelevance. People rediscovered their feet; the candle came back into its own; the infinite resiliency of the human spirit was demonstrated anew."[36] In a paperback compilation of *Times* articles on the blackout entitled *The*

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[34] Alfred E. Clark, "How Times Published: Paper Printed at Plant of Newark Evening News," *The New York Times* (Nov. 10, 1965) 2.

[35] "The Disaster That Wasn't," 20-25.

[36] "Aladdin's Lamp Blacks Out," *The New York Times* (Nov. 10, 1965) 6.

Night The Lights Went Out, editor A.M. Rosenthal wrote this Robinson Crusoe-like paean to the darkness:

> The blackout brought fears and mysteries; it also brought a certain exhilaration. In every man there is a corner of rebellion against the machine, and the blackout allowed us a brief period of freedom from its dominance. We were all delighted at the rediscovery of the importance of things that were not plugged into walls—things that were almost forgotten by us—most of all, the wonderful, wonderful candle. What a moment of triumph to know that the huge computers we really did not like and that we suspected really did not like us were lying massively dead and useless, but the old pencil sharpener still worked. It was modern man's closest equivalent to being alone on a desert island, and the great joy of making do bouyed us all. We knew we would be recaptured and brought back submissively to the prison farm of modern technology but it was good being free, loose and on the run for a few hours.

Rosenthal correctly anticipated that the blackout would make prime material for future scholars. "Psychologists will peer into the behavior of men under stress, sociologists will examine the suddenly torn fabric of modern life, economists will dissect the relationship of public utilities to public interests...And philosophers and theologians will search their minds for the meaning of man's position in a technological society which he found he neither really understood nor controlled, a most bewildering and frightening moment of awareness."[37]

Lewis Mumford was one of these scholars. A life-long New Yorker who was often gloomy about the possibility of human freedom in the face of what he called the "megamachine," Mumford nevertheless found cause for hope in the blackout. Near the end of *The Pentagon of Power,* the crowning volume in his series *The Myth of the Machine* series, Mumford wrote:

> For many [the 1965 blackout] proved an exhilarating experience: autos, which can function by their own power and light, kept moving: citizens supplemented policemen in directing traffic: trucks took on passengers: strangers helped one another: people found that their legs would transport them sufficiently when wheels failed: one set of young men and women gaily formed a procession, carrying candles, chanting in mock solemnity, 'Hark the Herald Angels Sing!' All the latent

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[37] *The Night The Lights Went Out,* 11-12.

> human powers that a perfect, smooth-running mechanical organization suppresses began to function again.[38]

For Mumford, as for Rosenthal, the blackout experience was something to be treasured, preserved, dissected for all it had to tell about human dependence on machines. While both stopped short of advocating deliberate acts of technological abstinence, it was the spiritually purifying effect of doing without electricity that they found most valuable. It was a short step from this belief to the conclusion that the blackout was not a disaster at all. "What seemed a calamity turned into an opportunity," Mumford wrote. "When the machine stopped, life recovered."[39]

At the center of many New Yorkers' blackout experiences, then, were three complementary discoveries: that everyday activities depended utterly on the uninterrupted supply of electricity; that this supply was in fact astonishingly fragile; and that life without electricity, or life less dependent on the electrical power system as structured, was not unthinkable. Though it is impossible to determine exactly how many people reached these conclusions in their own minds, anecdotal evidence suggests that they were not merely the opinions of a small group of left-leaning writers and critics of technology. Many New Yorkers were frustrated over the inconvenience caused by the blackout and angry toward Con Ed for its perceived incompetence, but these reactions were accompanied by the impulse to reflect on the unique experience. ("Like a play," Michael Barkun writes, "the sudden onslaught of disaster introduces the unusual and dramatic into lives that may have seemed bland and commonplace."[40]) Commuters forced to sleep on the floor of Grand Central Station told a newspaper reporter that they considered the blackout "the ultimate affront to American know-how." Some believed that the power failure meant "the death of the American dream" and that "basic creature comforts such as electric power could no longer be taken for granted." Many took the occasion to criticize Con Ed's electrical monopoly, advocating public ownership of utilities instead. And one Greenwich Village man pointed out, "That's what's wrong with a push-button society. All that has to happen is for one button not to work."[41]

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[38] Mumford, *The Myth of the Machine: The Pentagon of Power* , 409-412.
[39] Ibid.
[40] Barkun, *Disaster and the Millennium.* 163.

New Yorkers may have been especially predisposed to treat the blackout as a holiday from their complex urban existences. Under contract for the Office of Civil Defense, pollsters for the National Opinion Research Center fanned out through New York and other affected cities within days after the power was restored, interviewing a total of 1,313 people about their experiences during the blackout. They found that New Yorkers were more than twice as likely as residents of the other cities surveyed to have observed "people making a holiday occasion out of the blackout" or "strangers being more helpful and friendly to each other than usual." Among New Yorkers whose power was off the longest, fully 61.3 percent observed unusual friendliness among strangers and 26.3 percent observed holiday behavior.[42] Even after acounting for the fact that New York was blacked out for longer than the other cities surveyed, the city's residents seem to have been much more convivial during the disaster than people in Albany, Boston, Utica, or Waterbury.

New York's fast-paced environment was and is a paradigm of urban technological complexity and interdependency. To meet the demands of so many people crowded into so small an area, systems for electricity, gas, water, sewer, sanitation, communication, mass transportation, food distribution, and the control of traffic on the ground and in the air, to mention just a few, must function continuously and in perfect harmony. Participating in this artifice can be wearying, as anyone who has ever been stuck in a traffic jam or a crowded subway car can attest. (A sign posted on a New York overpass during the nineteen-fifties captured this variety of urban despair: "In the event of nuclear attack, drive off bridge."[43]) New Yorkers may have enjoyed the blackout more than their counterparts in smaller metropolitan areas simply because they found it *a bigger relief*. On November 9, 1965, the "city that never sleeps" finally got a good night's rest.

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[41] Bigart, "A Night of Confusion, Frustration and Adventure," 37; Phillips, "Blackout Vignettes," 37.

[42] National Opinion Research Center, *Public Response to the Northeastern Power Blackout* (unpublished manuscript, University of Chicago, October 1966) 22-26.

And Then There Was Light

New Yorkers' unexpected delight in rediscovering themselves and their city during the blackout did not slow efforts to restore power. The machinery of bureaucracy swung immediately into action to repair the machinery of life. Within minutes after the electricity went off, a phalanx of government and utility officials were phoning each other, trying to determine the cause and extent of the failure. (The telephone system, supplied by backup diesel generators, continued to operate throughout the blackout, though under considerable strain as curious Northeasterners placed tens of millions of extra calls to each other.[44]) Civil defense offices went on alert. President Johnson was notified at his ranch in Texas. New York Governor Nelson Rockefeller issued statements for radio broadcast to the public. Meanwhile, Con Ed utility workers faced the unprecedented task of restarting their system from an absolute standstill.

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[43] William Safire, "On Language: Linguaclip" *The New York Times Magazine* (Sep. 19, 1993).
[44] "Telephone Calls Set Record Here During Blackout," *The New York Times* (Nov. 11, 1965) 40.

Elsewhere in the Northeast, conditions had returned to normal relatively quickly. In most locations, workers first had to find the relays that had been thrown open by the overload, then close them by hand. Hundreds of miles of transmission lines had to be inspected, and generators had to be restarted using backup motors or water power, then carefully matched in phase. Utilities warned their customers to turn off all their lights except one in order to prevent another overload when the power came back on. Then, as power levels slowly crept back to normal, one region after another was re-lit. By 10:00 p.m., most of the CANUSE grid had been restored. Connecticut lagged until 11:30.[45]

New York City was a different story. Four of Con Ed's big generators, including "Big Allis," the nation's largest steam-turbine generator at the Ravenswood plant in Long Island City, were seriously damaged in the blackout. Ironically, while wild fluctuations in demand and loss of phase synchronicity had been the immediate causes of the local power shutdown, most of the damage to the generators was secondary -- caused by the power failure itself. "Big Allis" lacked backup power for the electric pumps that bathed its turbine bearings in lubricating oil. In the event of a local blackout, the plant's designers had counted on electricity being available from elsewhere in the grid. So when the lights went off across the Northeast, so did the pumps at Ravenswood. The bearings on the still-spinning turbines quickly burned out, their linings softening and peeling away under the intense friction, putting the generator out of commission for weeks. Turbines at Con Ed's Astoria plant in Queens burned out in a similar fashion, and the East River plant on 14th Street was damaged in an electrical fire.[46]

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[45] *The Night The Lights Went Out,* 25, 31.

Thousands of other pieces of equipment had to be inspected for damage, and Con Ed repairmen worked through the night to piece the system back together. Fortunately, a number of stations, including the Indian Point nuclear power plant on the Hudson River, had been spared any danger because they were out of service at the time of the blackout. Shortly before sunrise on November 10, Con Ed officials reached their moment of triumph: "After a final check came the count—'One...Two...THREE'—and 24 switches slammed into closed position, instantaneously transforming the Grand Central network area from a sea of blackness into a sea of light. So many men had reported for emergency duty, there were enough to stand at windows overlooking mid-Manhattan when the network went on the line and a spontaneous cheer rose from a score of throats."[47] By 7:00 a.m., thirteen and a half hours after the blackout began, Con Ed had restored electricity to the Bronx, the last borough without power. The company was able to meet Wednesday's peak demand of 4.3 million kilowatts using smaller generators that did not depend on electrically-pumped lubrication and by importing additional power from Connecticut and Niagara Falls.

By Friday, the blackout was already fading as a topic of conversation. That day Mayor Robert Wagner declared the emergency over and rescinded his appeal that the city conserve electricity.[48] Though New York had returned to its regular routines, a few things had subtly changed. There had been a small redistribution of wealth, for one; while the city's share of the overall losses from the disaster was put at $100 million, most of it the result of the interruption of trade, certain businesses had made a killing during the blackout, including hotels, restaurants, bars, rental car agencies, and hawkers of candles, flashlights, and batteries.[49] Hospitals, airports, and other critical facilities immediately began making plans to improve their backup power systems. And people discovered they had been drawn a little closer as a community: "A Connecticut woman yesterday found her fellow commuters less impersonal after spending the night on the 5:31 to Norwalk. 'Everybody recognizes everybody else now,' she said. 'Although they've seen me for 10 years, and they've done nothing but help me up the stairs, now it's a tip of the hat and a 'good morning, Phyllis, how are you today?'"[50]

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[46] John Noble Wilford, "Million-Kilowatt Generator Here May Stay Knocked Out a Week," *The New York Times* (Nov. 12, 1965) 36.

[47] *Around the System,* 16-17.

[48] Peter Kihss, "Emergency Over, Wagner Rescinds Save-Power Plea," *The New York Times* (Nov. 12, 1965) 1.

Dependence and Interconnection

During the weeks after the blackout, readers of the *New York Times* and other newspapers received a basic course in the politics, geography, and economics of electric power transmission. They discovered that with little fanfare the utilities of the northeast had spent the previous fifteen years building a loose power-sharing federation, so that Company A might be directly linked with Company B, but also indirectly through B to C, D, E, and dozens of others. "Most New Yorkers were surprised to learn...that the electricity they 'burn' may come from Boston or Niagara Falls, or as far away as Detroit" – and that as a result, a generator problem in Detroit might be felt in New York, one reporter wrote.[51] "It became apparent to New York City residents last week that flicking a light switch is not a wholly isolated act," noted another. "The blackout Tuesday drew attention to what lies behind the light switch -- an immensely complex and interlocking network of men, machines, and wires that is not infallible."[52]

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[49] Leonard Sloane, "Trade Loss Here Put at 100 Million," *The New York Times* (Nov. 11, 1965) 1, 38.

[50] Martin Tolchin, "Blackout Woes End in This Area," *The New York Times* (Nov. 12, 1965) 36.

[51] Gene Smith, "'Grids' and Such Cut Power Cost," The New York Times (Nov. 12, 1965) 36.

Interconnection made economic sense, utility spokesmen reassured the press. Coal- and oil-burning plants had reached a plateau of efficiency around 1950, forcing companies to pursue power pooling and improvements in transmission to keep electricity costs down. As the maximum voltages cables could carry rose from 345,000 volts in 1956 to 460,000 volts in 1962, the utilities realized it would be cheaper to band together to build big power plants near fuel supplies and share power over long distances than for each company to build enough capacity to meet peak local demand (assumptions which have subsequently been challenged; see below). New York went black because Con Ed had been unable to disconnect itself from the grid swiftly enough to avoid the power drain and frequency fluctuations to the north. But the utility could be forgiven, a Con Ed spokesman implied, since the power pools had also been designed as mutual protection societies. "It's like a group of friends swimming," the spokesman explained. "If one of them starts to sink, then it's natural for the rest to help. You may sink a bit yourself, but if enough of you help, you expect to pull through."[53]

But on November 9, it was as if the swimmers were handcuffed together. "Something pulled everybody down that night," the spokesman admitted.[54] United States Senator George Aiken, a Vermont Republican, criticized the very concept of utility interconnection, saying "We should construct our power system so that if one egg goes rotten, the others won't." The editors of the *Times* complained that "the utilities and the Federal Power Comission have so far shed little light on the blackout. The one thing that has emerged is that the technologically advanced concept of a regional pool to feed power from one area to another in periods of peak demand is far from foolproof. Until the weaknesses in this system can be discovered and corrected, the nation remains dangerously vulnerable to paralysis of its power supply."[55] The only thing that had prevented the power failures from cascading across the entire nation, many observers concluded, was that the utility networks were not yet connected into a single, national grid. George Orrok, vice president in charge of engineering at the Boston Edison Company, told reporters that if a national grid had been in place the entire country could have been "plunged into darkness in less than a second." Orrok said a worse blackout had been avoided only because the existing grid was "weak in spots."[56]

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[52] McCandlish Phillips, "Behind the Light Switch Lies Complex Power Network Covering Entire Northeast," *The New York Times* (Nov. 15, 1965) 42.
[53] Ibid.
[54] Ibid.

To many, the grid's breakdown indicated that private utilities pursuing efficiency and profit could not be trusted to provide reliable service. The utilities "have been given quasi-governmental powers to serve the public," the *Times* editorialized, "yet when its power failed Consolidated Edison compounded matters with a lack of candor -- or shall we say a super-optimism -- about the emergency and its duration that would be unacceptable from any government body."[57] *Times* reporter Eileen Shanahan observed that "demands [for more Federal electric power] have been heard increasingly in the last several days from the traditional advocates of government ownership of power facilities -- supporters of the cooperative power movement and others." Investigations of the blackout's exact causes would surely intensify the political contest between public and private power advocates, Shanahan predicted, since the answers would "point the way toward remedies that are certain to displease one side or the other -- and conceivably both -- in the fight over who is to own major electric power facilities and what kinds of facilities should be built in the future...The decisions on preventive measures may be based entirely on the political support each side can muster."[58] Chief Engineer Lurkis, meanwhile, warned that Con Ed should not be let off the hook just because the power failure had started in Ontario. "New York City's blackout problems are built in and cannot be solved by placing the blame across the borders or elsewhere," Lurkis asserted in his report. He traced the local blackout to Con Ed's overreliance on imported power, its failure to install adequate load-shedding devices, and poor training and inadequate communication among system operators. "Con Edison consistently wants returns equal to private industry's earnings but does not want to be held by the same rules that prevail in private industry," Lurkis concluded. "The losses and costs due to blackouts and brownouts should all come out of the pockets of Con Edison's stockholders and not out of the purses of consumers."[59]

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[55] "Paralysis of Power," *The New York Times* (Nov. 11, 1965) 46.

[56] Orrok and Person quotations from: Gene Smith, "Utilities Agree on a Prediction: Statewide Failures Can Recur," *The New York Times* (Nov. 11, 1965) 38.

[57] "Paralysis of Power," 46.

For others, the grid's collapse conveyed a more general warning about the dangers of size, complexity, and centralization. In a meditation entitled "Fail-Safe Syndrome," *Times* science reporter Walter Sullivan wrote of cosmologist Fred Hoyle's argument that the same technology that made it possible to feed, clothe, and shelter an ever-growing number of people would, in time, destroy civilization. As technology advances, Sullivan summarized, it becomes increasingly complex. "Centralization and bigness make for greater production efficiency, be it the generation of electric power or the prodessing of food. But such societies become increasingly vulnerable to catastrophic disruption....Hoyle argues that our civilization will become so vulnerable that it will ultimately succumb to some such threat as a new disease, a nuclear war, or simply a general collapse." Sullivan concluded that the "spirit of public service and cooperation in the face of common danger" that New Yorkers had displayed during the blackout contradicted Hoyle's argument. Still, Sullivan wondered whether humanity would ever "recognize the ultimate crisis in uncontrolled technological development."

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[58] Eileen Shanahan, "Politics and Blackouts," *The New York Times* (Nov. 13, 1965) 23.
[59] Lurkis, *The Power Brink,* 59-60, 181-182.

Such cautions notwithstanding, the net effect of the 1965 blackout was to *increase* rather than decrease Americans' dependence on a complex, centralized system of electrical power distribution. The blackout had come as an embarrassment to the utility companies and to the politicians charged with regulating them, and it touched off a flurry of official investigations aimed at affixing blame and restoring public faith in the power system (both electrical and political). The Federal Power Commission, the Federal Communications Commission, the City of New York, the New York State Public Service Commission, and agencies in other states all launched inquiries into the blackout's causes and ways to prevent a recurrence. These investigations uniformly concluded that a national electrical grid, had it been in place, would have prevented the blackout altogether. "The principle of pooling and interconnection is basically sound, as indicated by the fact that the kind of power failure just experienced has rarely occurred," said Robert

Person, president of the Edison Electric Institute, an industry think-tank.[60] "Nothing that has occurred indicates that we should go back to bows and arrows or isolated and inefficient generating plants," remarked the Chairman of the Federal Power Commission, Joseph Swidler.[61] "The prime lesson of the blackout," the Federal Power Commission insisted in its report to President Johnson, "is that the utility industry must strive not for good but for virtually perfect service...Well-integrated power pools add strength and reliability to service from all the interconnected systems. The so-called CANUSE network, within which the failure occurred, is not yet such an integrated power pool."[62] The problem was thus defined by industry leaders and their government overseers not as one of too much complexity, but too little -- a common but often misguided answer to the challenge of reliability, as we will see shortly.

With the federal government's backing, the utilities undertook a series of improvements to the grid system. More high-voltage interties between the regional utility groups were constructed, along with equipment to sense network irregularities and give operators more time to act during a crisis. Con Ed bought computers designed to "anticipate trouble and help solve problems before they reach crisis stage." New load-shedding devices were installed, some of them designed to cut off power to blocks of customers automatically in the event of instabilities in the alternating-current frequency. Utilities in the Northeast set up emergency communications lines between the various companies' control centers.[63] A year after the blackout, while still urging stronger interconnections, FPC officials concluded with satisfaction that the utilities had taken "numerous steps to increase power reliability" and declared that the chances of another power failure triggered by the same cause were now "virtually zero."[64]

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[60] Orrok and Person quotations from: Gene Smith, "Utilities Agree on a Prediction: Statewide Failures Can Recur," *The New York Times* (Nov. 11, 1965) 38.

[61] *Around the System*, 20.

[62] Federal Power Commission, *Northeast Power Failure: November 9 and 10, 1965: A Report to the President* (Washington: Government Printing Office, December 1965) 1.

[63] *Around the System*, 20.

Hoping to prove the regulators right, the utilities formed nine "regional reliability councils" under the umbrella of the Princeton, N.J.-based North American Electric Reliability Council. The NERC tracked system disturbances and published annual assessments of its members' abilities to share power and meet peak demands. Under the NERC's direction, the utilities joined into four "Interconnections" blanketing the U.S. and Canada, the largest of which, the Eastern Interconnection, now covers all or part of 38 states and three provinces. Within each Interconnection, the frequency of alternating current is the same at all points, ensuring that demand at any location in the Interconnection can be supplied by generation located at any other location. At the same time, however, a generation or transmission failure anywhere in the grid sends waves of stress throughout the Interconnection, with results that can be vexing for local system controllers. Interestingly, the utilities stopped short of creating a national or continental Interconnection: "technical and economic reasons [made it] impractical to use alternating current transmission lines to tie the major Interconnections to each other," the NERC explains.[65]

During the nineteen-seventies, the utilities began to discover that bigger grids could cause bigger headaches. The laws of physics imposed unexpected difficulties: capacitors installed on some long transmission lines to compensate for the storage of energy in the lines' magnetic fields, for example, had resonant frequencies that were so close to those of generating equipment that catastrophic mechanical vibrations destroyed several turbogenerators shafts. There were also problems of control and communication. In a system monitored from multiple, independent control centers, decisions made by operators in Florida could conflict with those made in Saskatchewan and vice versa. "It is becoming apparent that the increasing complexities of the nation's electric energy system are rapidly outstripping its capabilities," concluded a systems engineer at the federal Energy Research and Development Administration.

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[64] Eileen Shanahan, "Giant Blackouts Still Possible, U.S. Study Finds," *The New York Times* (Nov. 6, 1966) 1, 44.

[65] North American Electric Reliablity Council, *1989 Reliability Assessment: The Future of Bulk Electric System Reliability in North America 1989-1998* (Sep., 1989) 22.

> Our interconnected energy systems seem to be evolving into a new condition whereby 'more' is turning out to be 'different.' As they become more tightly interconnected over larger regions, systems problems are emerging which neither are presaged, predicted, or addressed by classical electrical engineering and which are no longer amenable to ad hoc solution...Accordingly, the industry has been devoting considerable effort to studying what has become known as the dynamic stability problem...[and] it is acknowledged that the larger, more tightly interconnected system is behaving in a fashion qualitatively different from that of earlier, smaller systems...Analyzing effective control strategies is in its infancy.[66]

Jack Busby, the president of the Pennsylvania Power and Light Company, put it more bluntly: "We hoped the new machines would run just like the old ones we're familiar with, and they sure as hell don't."[67]

The rush to make power grids more rigidly interconnected obscured an alternative means of protecting consumers from blackouts: building more decentralized generation systems that would be inherently resistant to system-wide failure. Computer-monitored high-voltage interties between utilities might enable them to withstand *predictable* kinds of breakdowns, critics pointed out, but only a more modular, redundant, flexibly-interconnected system would be able to handle massive, unforeseen disruptions like the 1965 failure. This distinction, as conservation and renewable-energy advocates Amory and Hunter Lovins have put it, is one between *reliability* and *resilience.* The Lovinses write, "The property being sought when one designs a system for resilience is that it be able to *survive* unexpected stress: not that it achieve the greatest possible efficiency all the time, but that it achieves the deeper efficiency of avoiding failures so catastrophic that afterwards there is no function left to *be* efficient."[68]

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[66] L. H. Fink, "Systems Engineering Challenges Emerge as Electric Energy Network Increases in Complexity," *Professional Engineer* (Dec., 1976) 20-21; quoted in Lovins and Lovins, *Brittle Power*, 138-39.

[67] Richard F. Hirsh, *Technology and Transformation in the American Utility Industry* (Cambridge, U.K.: Cambridge University Press, 1989) 87.

But by the time of the 1965 power failure, the technological and economic momentum behind further interconnection was already too strong to be deflected. The economies of scale provided by large generating units (maximum output had risen from 5 megawatts in 1903 to 1,000 megawatts in 1965), together with improvements in transmission efficiency, had made the industry the most productive in the U.S.[69] At $70 billion in 1968 dollars, the total value of the utilities' plant and equipment also far outstripped that of other industries.[70] Electrical demand seemed certain to continue growing at an annual rate of about 7 percent, doubling every ten years. And as long as the cost of electricity continued to decline, the public utility commissions regulating consumer rates remained reluctant to interfere with the utilities' plans for growth and interconnection. The "stakeholders" in the electrical power industry -- utility managers, regulators, investors -- "had forged an implicit consensus concerning the choice, management, and regulation of a technological system," writes industry historian Richard Hirsh. "As long as benefits continued to accrue to everyone, the consensus would remain intact."[71] Larger electrical grids, one science writer concluded, would become "an inevitable consequence of consumer demands for cheaper power and the continued advance of technological development, especially computers, automated equipment and more efficient extra-high voltage transmission lines, regardless of who wants what."[72]

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[68] Lovins and Lovins, *Brittle Power,* 191. Emphasis in original.
[69] Hirsh, *Technology and Transformation in the American Utility Industry* , 83.
[70] Landsberg and Schurr, *Energy in the United States: Sources, Uses, and Policy Issues,* 208.

The 1977 Blackout

On July 10, 1977, Con Ed chairman Charles Luce told the Subcommittee on Energy and Power of the U.S. House of Representatives that he could "guarantee" that there was no likelihood of a recurrence of the 1965 blackout.[73] Three days later, a series of lightning strikes, equipment failures, and operator errors disrupted Con Ed's power connections to the surrounding grid and left the utility's internal generating capacity nearly two million kilowatts short of demand. The result was a 25-hour city-wide blackout and a night of lawlessness that cost Con Ed, other businesses, and the city government an estimated $1 billion.[74]

In one way, however, Luce had been correct. The precipitating cause of the 1977 breakdown was exactly the reverse of the 1965 crisis. Then, Con Ed managers had failed to anticipate the results of being so tightly interconnected to the Northeast power grid. This time, they failed to foresee the consequences of being wholly *unconnected*. In both cases, though, power system controllers were ambushed by a combination of breakdowns they had not thought possible, an emergent aspect of the system's very complexity and tight coupling. It was as if the technical lessons of the 1965 blackout had to be learned all over again. And this time, there was an added fact to be reckoned with: the outage had unleashed a night of warlike social disorder in the city. In the years since 1965, clearly, New York had come to depend on its fragile electrical network in new and troubling ways.

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[71] Ibid., 86.
[72] Howard Simons, "Inquest on Power," *The New Scientist* (Nov. 25, 1965) 569.
[73] Lovins and Lovins, *Brittle Power*, 51.
[74] The estimate was Charles Luce's. Ibid., 65.

The region's basic geographical and political boundaries had enforced New York City's isolation as an electric archipelago even after the grid improvements that followed the 1965 blackout. Con Ed's major links to the Eastern Interconnection all squeezed through a narrow corridor in Westchester County. A strong 345,000-volt line underneath the Hudson River tied Con Ed to power sources in New Jersey, but this line's phase-regulating transformer had failed the previous September. On July 13, 1977, the Indian Point 2 nuclear plant was out of commission with a failed pump seal, the Bowling Point 2 fossil fuel plant was down with boiler problems, and the Astoria 6 plant had suffered a turbine failure. As a result, the total generating capacity available within the Con Ed system was only 3.9 million kilowatts. A heat wave gripped New York that day with temperatures as high as 93° F, and power-guzzling air conditioners had pushed total demand to 6.1 million kilowatts. The extra 2.3 million kilowatts were being imported through the Westchester County lines.[75]

Early that evening, a line of thunderclouds crossed rapidly into Westchester. At 8:37 p.m. lightning struck two 345,000-volt overhead transmission lines running from the Indian Point 3 nuclear plant to Millwood, N.Y., where six major power lines intersected. Most transmission lines are equipped with circuit breakers designed to open when lightning strikes and then reclose automatically, momentarily isolating the overload until it can drain off into the ground. This time, the circuit breakers opened but failed to reclose; one had a loose locking nut, and the reclosing circuit on the other had been disconnected and not yet replaced. With nowhere to send its power, the Indian Point reactor shut down automatically, reducing the power available to Con Ed by 0.9 million kilowatts. Another 345,000-volt line across the Hudson tripped out after an improperly-designed protective device failed to recognize that the first two lines had already isolated the lightning flash. The lost power from Indian Point and the three transmission lines, however, was made up immediately by power flowing through Millwood on a line from upstate New York and Canada.

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[75] Sources for my description of the blackout's technical progress include: "Con Ed seeks light, less heat, on system blackout," *Electrical World* (Aug. 15, 1977) 25-28; Philip Boffey, "Investigators Agree N.Y. Blackout of 1977 Could Have Been Avoided," *Science* (Sep. 15, 1978) 994-98; Norman Clapp, *State of New York Investigation of the New York City Blackout* (Jan., 1978); Peter Kihss, "Con Ed Had 15 Minutes to Pull Switch," *The New York Times* (July 18, 1977) 1, 49; Lovins and Lovins, *Brittle Power*, 51-58; Victor McElheny, "Improbable Strikes by Lightning Tripped Its System, Con Ed Says," *The New York Times* (July 15, 1977) A2; G.L. Wilson and P. Zarakas, "Anatomy of a Blackout," *IEEE Spectrum* (Feb., 1978) 39-46.

William Jurith, the Con Ed system operator at the company's Energy Control Center near Lincoln Center, sent an alarm to all the city's generating stations requiring them to increase power production and directed that jet aircraft-type turbines at Astoria be put into service. But these generators provided only half the extra power Jurith had expected; some were shut down for inspections, others malfunctioned, and some were unmanned. At 8:56 p.m. another lightning strike short-circuited two of the three lines from Millwood to New York City. One of these reclosed. The other stayed open, and its loss caused a power surge that overloaded yet another line. Now only a single cable from New York to the north was intact. This cable was operating at 32 percent over its emergency rating, and a smaller tie to New Jersey was overworked by 20 percent.

The double lightning strike, Con Ed president Arthur Hauspurg later insisted, had been completely unforeseeable. That sort of thing "just never happens," he said.[76] At this point, wrote *Science* magazine writer Phillip Boffey, "the situation could still have been saved by alert, well-trained operating personnel. They could, for example, have shed some load or increased generation to restore equilibrium. But Con Ed's control room succumbed to confusion and panic and did neither effectively."[77]

Though flow meters and a teletype machine in the control room indicated that the third Millwood line was down, Jurith believed that it was still operating. Operators in an adjacent room, where there was a flashing screen with a high-pitched alarm, knew that the line was inoperable, but they failed to pass that fact on to Jurith. Had he known, he might have dispatched workers to reclose the line manually. (On the other hand, this might have been difficult, since Con Ed's UHF and VHF radio networks for communication with maintenance crews were both inoperative due to the failure of backup power supplies.) Dispatchers at the New York Power Pool control center in Guilderland advised Jurith repeatedly to shed load. He resisted, instead calling the chief system operator at home for advice. The chief ordered a 5-percent voltage reduction at all Con Ed substations to reduce load. Ten minutes later, the voltage was reduced again. Two Westchester County areas were blacked out, but the remaining load was still too high.

The last straw came at 9:19 p.m. The line from Millwood north to Pleasant Valley, after being overloaded beyond its 20-minute emergency rating for 23 minutes, finally tripped out. Thermal expansion in the line had caused it to sag to the ground and short-circuit. The Long Island and New

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[76] McElheny, "Improbable Strikes by Lightning Tripped Its System, Con Ed Says," A2.
[77] Boffey, "Investigators Agree N.Y. Blackout of 1977 Could Have Been Avoided," 995.

Jersey ties, normally carrying a combined 0.8 million kilowatts but suddenly faced with a load three times as great, failed within minutes. Con Ed now had 4 million kilowatts of local generating capacity with which to meet a demand of 5.7 million kilowatts.

After the 1965 blackout, a sequence of seven load-shedding switches had been installed in the Energy Control Center. Jurith could have disconnected as much as a quarter of the system's load manually using these switches, perhaps saving the rest of the city, but the controls required that a master switch be operated first to prevent accidental shedding. Jurith went through the procedure but never set the master switch properly, and nothing happened. As generating frequency spiraled downward due to the excessive demand on the in-city generators, automatic load-shedding equipment (also installed after 1965) stepped in, quickly and mindlessly cutting off power to neighborhood after neighborhood. As was discovered later, however, the automatic devices shed load too quickly, creating a frequency surge and voltage fluctuations that forced the remaining generators off-line. "Con Ed engineers never dreamed their system would be reduced to such a small island," Boffey observed, "so they never bothered to analyze what would happen to system voltages after automatic load shedding on an isolated system."[78] By 9:34 the entire Con Ed system was black -- thanks partly to the safety systems that had been installed after 1965 to prevent just such a failure. This time, it would take 25 hours to restore power fully, in part because pumps providing cooling oil to the main underground cables lacked backup power and restoring oil pressure proved difficult. "Once the system failed, its very complexity slowed recovery," wrote *New York Times* reporter Victor

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[78] Ibid.

McElheny. Con Ed was in the position of a "turtle on its back struggling to right itself."[79]

Blackout Looting

While Con Ed struggled, New Yorkers endured 25 of the longest hours in the city's history. Once the electricity went off the assumption quickly spread, thanks to memories of 1965, that the city was in for a long night without power. Violence and looting erupted in all five boroughs, with the worst unrest centered in black and Hispanic neighborhoods.[80] Stores and shops, their burglar alarms disabled by the power outage, made easy pickings -- especially since most had already closed for the night when the power went off. (In 1965, by contrast, the power had gone off early enough in the evening for many store owners to decide to stay in their stores overnight.) Darkened traffic signals and street lights caused numerous traffic accidents and made it dificult for police and fire officials to respond to calls for help. More than 1,600 businesses were damaged, most in Brooklyn and the Bronx, and 900 fires were reported, 50 of them serious. Over 3,300 people were arrested. The blackout forced most banks, offices, stores, theaters, and financial exchanges to close for a full day, resulting in hundreds of millions of dollars in lost business.[81]

The failure of backup generators at many critical facilities compounded the crisis. The New York state legislature had mandated after the 1965 blackout that all hospitals be equipped with diesel auxiliary generators, but at Bellevue Hospital the required auxiliary system failed after only a few minutes. Medical staff resorted to squeezing air bags by hand to provide oxygen to patients who had been on mechanical respirators.[82] Backup generators also wheezed to a halt in several police precincts, complicating the response to the city-wide crime wave. Gasoline pumps for police cruisers were left powerless, as were the boosters and repeaters needed to maintain radio contact between station houses, patrol cars, and foot-patrolmen. The main cause of the failure of backup equipment: During required monthly inspections, officials had tested most generators for only a few minutes at a time, failing to determine whether they would perform well under real emergency conditions.[83]

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[79] Victor McElheny, from *New York Times* News Summary carbon copy in McElheny's files, dated July 20, 1977.

[80] Harlem, East Harlem, the South Bronx, Jamaica in Queens, and the Bedford-Stuyvesant, Bushwick, Crown Heights, and Williamsburg sections of Brooklyn were the worst hit.

[81] Robert D. McFadden, "New York's Power Restored Slowly; Looting Widespread, 3,300 Arrested; Blackout Results in Heavy Losses," *The New York Times* (July 15, 1977) A1-A2; Robert Curvin and Bruce Porter, *Blackout Looting! New York City, July 13, 1977* (New York: Gardner Press, Inc., 1979) xiv-xv, 24, 25.

Though there were examples of gallantry and perseverance that night -- flashlight-wielding doormen helped hundreds of tenants up darkened stairways, and concerts and plays darkened by the power failure continued by candlelight -- the major impressions were of pathos and dread. One woman stranded at the top of a high-rise apartment complex recounted her terror at hearing crashing noises as looters climbed upward through the building. They stopped just two floors below her.[84] Many New Yorkers were puzzled by the contrast with the peaceful example set in 1965. "There seemed agreement that much of the old élan was sadly lacking," wrote one journalist. "If the 1965 blackout had produced complaints, it also produced people who laughed at their complaints, accepting their ordeal with infinite patience and great style. On Wednesday, with looters in some neighborhoods and indifference in others, there was precious little humor to mitigate the darkness, the fear, the inconvenience."[85]

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[82] Lawrence K. Altman, "Bellevue Patients Resuscitated With Hand-Squeezed Air Bags," *The New York Times* (July 14, 1977) A;

[83] Curvin and Porter, *Blackout Looting!*, 70.

[84] Deirdre Carmody, "Pathos, Heroics, Humor On a Night to Remember," *The New York Times* (July 15, 1977) A14; Frank J. Prial, "New York Theaters Bouncing Back Faster Than Its Restaurants After the Blackout," *The New York Times* (July 15, 1977) A14; Curvin and Porter, *Blackout Looting!*.

The main difference between 1965 and 1977 was easy to discern from newspaper headlines: "Ravaged Slums Face an Uncertain Future," "Social Overload," "When Poverty's Part of Life, Looting is Not Condemned." Predictably, racial minorities and the poor had been hardest hit by the seventies' rampant unemployment and inflation, the twin components of the "misery index" so frequently cited during the Carter administration. During the ten years from 1967 to 1977, unemployment among African-Americans nationally doubled from 7 to 14 percent, while the cost of living as measured by the Consumer Price Index rose by 86 percent.[86] In 1965, New York City had spent $100 million on programs for youth in poor areas, but in 1977, with the city barely recovered from a brush with bankruptcy, "all that is out the window," as former Mayor Robert Wagner observed.[87] Even Ronald Reagan was moved by the blackout to remark that "It makes you wonder what we have done to this society in that short period of time."[88]

To some observers, social conditions in parts of the city had grown so desperate than even the slightest disruption could have touched off the looting. A Ford Foundation study of the blackout concluded, "The root of it all, the fundamental source, was the poverty and growing hardship both in the old ghettos and in neighborhoods more recently inhabited by the city's poor...To say [the looters] were simply hoodlums ignores the social and economic realities of urban life which became startingly visible in the darkness of the night of July 13, 1977."[89] Anthony Bouza, deputy chief of the New York Transit Police, observed that "the blackout [was] irrelevant to what happened in the streets, except as a precipitate cause, a match. It could have been a shooting, a boy hit by a police car, or the clearing of a park. The combustible substance was already there."[90] In this sense, the 1977 blackout was a social disaster, not just a technological one. Like the riots following the Rodney King verdict in Los Angeles in 1992, it pointed to major shortcomings in the city's economic system, refocusing public attention, at least briefly, on persistent race- and class-based inequalities.

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[85] Richard Severo, "Two Blackouts and a World of Difference," *The New York Times* (July 16, 1977) 8.
[86] Curvin and Porter, *Blackout Looting!*, 183.
[87] "Who Gets the Blame?" *New York* magazine(Aug. 1, 1977) 33-34.
[88] Ibid.

But it is absurd to insist that the lawlessness of that night was no more than a flare-up of social and economic tensions, while ignoring the crucial part played by the city's technological infrastructure. As two electrical engineers summarizing the blackout's lessons noted, "The use of electricity has grown from its inception at the turn of the century as a nonessential convenience to a major national resource necessary to meet the most essential needs of society."[91] The power failure, then, was not simply a "match" that ignited a "combustible substance." It would be more accurate to say that *the social order in New York City had come to rest on the availability of electricity* in such a way that its absence was like releasing a brake on neighborhood unrest. Norms of respect for private property, the blackout showed, hinged on whether that property was protected by a functioning electronic burglar alarm. People's perception that they could get away with looting was greatly strengthened by the knowledge that law enforcement had been immobilized. This, too, is part of the "context of equipment" that can be "lit up" by disaster. If a city's electric power network is so brittle and monolithic that a thunderstorm can trigger a complete shutdown of essential services, that fact should be part of any assessment of the city's social stability. (The New York State Court of Appeals, the state's highest court, recognized Con Ed's implicit obligation to maintain service by ruling against the utility in 1981 in a multimillion-dollar suit over food spoilage at city grocery stores.)

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[89] Curvin and Porter, *Blackout Looting!*, 185.
[90] Ibid.
[91] Wilson and Zarakas, "Anatomy of a Blackout," 46.

What could have been done to lessen New York's dependence on the Con Ed system, thereby increasing stability? Smaller generating units located closer to critical facilities and managed independently from the grid might have ensured that police stations, hospitals, and traffic lights remained energized. A report on the 1977 blackout prepared for the U.S. Department of Energy's Office of Policy and Evaluation found: "There is no question that [decentralized sources]...would have helped greatly provided that they had been properly integrated into the power system under conditions of cascading outage. This means that fail-safe procedures must exist to ensure that [the decentralized sources] continue to function...and are, in fact, connected to the essential loads, i.e. [vital functions in] buildings, government services, traffic lights, etc....The demand for essential services is estimated to be in the range of several percent of total demand. Thus, several hundred megawatts of [decentralized sources]...might have prevented the loss of essential services."[92]

Just as in 1965, however, the major technological response to the blackout was a shoring-up of the existing power network rather than an attempt to supplement it with alternative sources. Within days Con Ed announced it would take "super-extra precautionary measures" to prevent more blackouts, including installing more backup generators and adding staff at control centers and at previously automated facilities. Later, the company said it would improve the training of system operators, further strengthen interties with other utilities, and redesign the Energy Control Center to facilitate decision-making in crisis situations.[93] One skeptical reporter remarked that "it could not be determined immediately whether the changes were substantial or were meant to regain a measure of public confidence in the system's reliability," but in fact both goals were crucial to the utility's survival: the blackout had greatly amplified calls for government takeover of the power grid, especially in Westchester County, where officials had already commissioned a $100,000 study of the possibility.[94] A group called the Coalition for a Publicly Owned and Democratically Controlled Utility announced that "The Real Issue!! is Public Power versus Con Edison, a profit-making monopoly," and reminded New Yorkers that "there IS something they can do about the highest rates in the country...[and] the arbitrary cut-offs of service."[95] All this may have contributed to a novel hint of humility in Con Ed's public stance. Though the utility initially called the multiple lightning strikes "acts of God," it later admitted that a number of human and technical failures, notably Mr. Jurith's failure to shed load manually, had brought about the blackout and the long delay in restoring power. Said chairman Luce, "From now on I'll never feel I have anything under control again."[96]

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[92] Systems Control Inc., *Decentralized Energy Technology Integration Assessment Study* (Dec., 1980); Quoted in Lovins and Lovins, *Brittle Power*, 280-81.

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[93] Consolidated Edison press release, Aug. 2, 1977, McElheny files.

[94] Wolfgang Saxon, "Con Ed Acts to Cut Chance of Blackouts," *The New York Times*, (July 17, 1977) 1, 39; "Issue and Debate: Can Westchester County Quit Con Edison?" *The New York Times* (Dec. 14, 1976) 74.

[95] Coalition for a Publicly Owned and Democratically Controlled Utility, broadsheet, McElheny files.

Turning to Decentralized Energy

In 1979 the director of the Pentagon's Defense Civil Preparedness Agency[97] became alarmed by the ongoing energy crisis of the nineteen-seventies and by the spectacle of the nation's largest city stripped of electric power. He commissioned Amory Lovins, a physicist and energy strategist, and Hunter Lovins, a lawyer and political scientist, to assess the fragility of the national energy system. The result was the Lovinses' 1982 book *Brittle Power: Energy Strategy for National Security.* In it the the couple argued that energy-delivery technologies as highly centralized in those in the U.S. invited catastrophe both through system accidents and through acts of terrorism.[98] The Lovinses called for incremental changes to increase these technologies' resilience -- their ability to withstand unpredicted disturbances -- and for conservation and efficiency measures to reduce the nation's prior dependence on them. The most important contribution of their study, however, was to refute the old assumption that large, centralized, monopolistic energy systems like electrical utilities were necessarily more efficient and reliable than other kinds of systems. Energy sources that were small, simple, diverse, dispersed, redundant, and autonomous, they found, would be not only more resilient than the old energy networks, but also cheaper:

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[96] "Where Were You When the Lights Went On?" *Fortune* (Aug., 1977) 20.

[97] Now the Federal Emergency Management Agency.

[98] Novelist Tom Clancy acknowledged the potential for terrorism involving the national electrical grid in *Patriot Games*: "There were ways to hurt America, to get attention in a way that no revolutionary group ever had. What, for example, if he could turn out the lights in fifteen states at once? Alex Dobbens knew how. The revolutionary had to know a way of hitting people where they lived, and what better way, he thought, than to make unreliable something they took for granted? If he could demonstrate that the corrupt government could not even keep their lights on reliably, what doubts might be put in people's heads next? America was a society of things, he thought. What if those things stopped working? What then would people think? He didn't know the answer to that, but he know that something would change, and change was what he was after." (New York: Berkley Books, 1987) 334.

> The diseconomies [of centralized energy systems using large, expensive generating plants] are far more numerous, and seem collectively larger, than the economies...Of course, there are still tasks for which big systems are appropriate and cost-effective. It would, for example, be almost as silly to run a big smelter with many little wind machines as to heat many houses with one big reactor. Mismatching scale in *either* direction incurs unnecessary costs...Thus the extreme centralization which is at the root of America's energy system is not economically essential and is probably an economic mistake or liability.[99]

In the construction of large electrical generating plants, the Lovinses pointed out, money is saved through the dilution of costs for setup, labor, and materials, but money is lost through the cost of interest on loans, the need for new designs to cope with added complexity, expensive onsite fabrication, and the lack of standardization. Big plants have higher operating costs as well, since they can fail in more ways than smaller plants, are more difficult to repair, and have longer downtimes.[100] The cost of transmission and distribution over long, high-voltage cables, moreover had risen by the early nineteen-nineties to a steep $1.50 for every $1 spent on generation.[101] Security against system breakdowns, the Lovinses concluded, could be achieved through a gradual shift to dispersed, renewable sources that, fortuitously, would also be economically and environmentally sound.

As the Lovinses described it, this shift to more resilient technologies would also have interesting political results. Resilient technologies get that way partly because of a set of inherent qualities that also happen to enhance democratic participation in technological decision-making. These technologies are local (geographically and socially close to users), comprehensible (easy to use), and user-controllable (capable to doing what users want). They are also simple (so that "anyone can see what is wrong" when they break), accessible (allowing people to form intelligent judgments about their use), and optionally autonomous (capable of contributing to an interconnected network, but also able to stand alone if necessary).[102] The means of electrical generation highest on the Lovinses' list of resilient technologies included mini-hydroelectric stations, photovoltaic cells, and windmills, all devices that consumers can easily install and maintain. "The problem [renewable energy experts] had feared was that there might not be enough attractive renewable sources to meet the needs of an advanced industrial economy," they wrote. "The problem they are actually encountering, however, is that there are too many."[103]

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[99] Lovins and Lovins, *Brittle Power*, 220-23.

[100] Ibid., 335-346.

[101] Leslie Lamarre, "The Vision of Distributed Generation," *EPRI Journal* (April/May, 1993) 11.

Many of the concepts offered in *Brittle Power* seemed far-fetched in 1982.[104] Utility companies were beginning to recognize the liabilities attached to large construction projects (especially nuclear ones -- see chapter 3) but most had turned to demand-management and conservation measures as a way to defer questions about how best to meet future electrical demand.[105]

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[102] Ibid., 190, 202, 205, 216-17.

[103] Ibid., 373.

[104] There was, however, solid historical precedent for many of the Lovinses' ideas. The city of London, for example, resisted relying on a single, centralized electric utility from the very first days of electrification. A patchwork of small, privately- and publicly-owned companies covered the city, each making a profit and providing "reliable and affordable power adapted to local needs...London's borough governments, perceiving their own political significance and autonomy as inextricable from the infrastructure upon which they depended economically, consistently opposed Parliamentary efforst to consolidate the grid. The boroughs favored a highly decentralized electrical system that each could control more easily." See Richard Sclove, "Technological Politics as if Democracy Really Mattered," in Michael Shuman and Julia Sweig, eds., Technology for the Common Good (Washington, D.C.: Institute for Policy Studies, 1993) 65-66; Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983) chapter 9.

[105] The growth of demand had slowed to about 3 percent per year by 1982, and by 1993 had declined further to 1.5 percent per year. North American Electric Reliability Council, *12th Annual Review of Overall Reliability and Adequacy of The North American Bulk Power Systems* (Aug., 1982) 8; *Reliability Assessment 1993-2002* (Oct., 1993) 16.

Fourteen years later, however, the Lovinses' ideas about small, dispersed generating units have entered the mainstream of utility industry thought under the label "distributed generation." *EPRI Journal,* a publication of the Electrical Power Research Institute, noted in 1993 that heightened competition, technological advances, a strong environmental movement, and new legislative and regulatory initiatives were "causing analysts to question the existing paradigm of central-station-based resource planning."

Jarred by new Federal legislation in 1992 that made it easier for independent power producers to compete with the big utilities, the industry has begun searching for ways to reduce costs by exploiting "economies of mass production" rather than economies of scale. This might mean installing hundreds of 100- to 3,000-kilowatt diesel and internal combustion engines, gas turbines, fuel cells, or photovoltaic arrays wherever power is most needed in a utility's service area. These distributed units could provide industrial and commercial customers with a more reliable electricity supply, and would also be more acceptable generating sources in communities opposed to the siting of large facilities. But as the Lovinses foresaw, the main logic behind the shift to distributed generation is still economic. "The feeling of some in the industry is that if utilities don't offer these kinds of [distributed] services, independent power producers will," says one EPRI economist.[106]

Regulatory changes underway in California, moreover, may soon free electricity consumers from their traditional ties to large utility companies. In a move that is likely to spread to other states, California's Public Utility Commission voted in April, 1994, to create a legal mechanism allowing consumers to shop for low electric rates among power providers inside and outside the state, just as the 1982 Bell breakup allowed people to hire the long-distance telephone company of their choice. Called "retail wheeling," the system is supported by utility customers who have "learned how hard it is to negotiate with a monopoly" and who want "a true choice of supplier," writes Barbara Barkovich, a California energy consultant.[107] The system may go into effect as early as 1996, putting even more pressure on private utilities to phase out high-cost generation facilities like nuclear plants in favor of smaller, more distributed sources. (Pacific Gas & Electric's Diablo Canyon reactor, which was built at $4.5 billion over its original $1 billion budget and is shut down a minimum of 50 days per year for refueling, is among the plants that may quickly become white elephants.) The California commission's vote on retail wheeling "is going to be a landmark decision that will pave the way for a radical restructuring of the electric power industry," predicts Michael Foley of the National Association of Regulatory Utility Commissioners.[108]

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[106] Lamarre, "The Vision of Distributed Generation," 8.

It took the Arab oil embargo, consequent consumer protests over high energy costs, the 1965 and 1977 blackouts, and years of low growth in electrical demand to convince utilities that bigness was the wave of the past. "The utility industry appears to have lost the technological imperative for remaining a monopoly," Richard Hirsh wrote in 1989. "Because low growth rates combined with financial troubles and public resentment against 'big' technologies militate against building large plants, utilities prefer to add capacity in small, quickly installed modular units. But these technologies do not require the giant consolidated utility companies to finance and build them...Public pressure and new laws make a return to 1965 impossible, with the result that utility managers are indeed losing control of their industry."[109]

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[107] Barbara Barkovich, letter to the Business Page editor, *The New York Times* (July 10, 1994) III: 11.

[108] Seth Mydans, "California Nears Competition Among Electricity Providers," *The New York Times* (April 21, 1994) A14; Agis Salpukas, "A Utility Gets Ready to Compete," *The New York Times* (May 11, 1994) D1, D6.

The role of the blackouts in these changes was, if not decisive, then at least significant. The Lovinses' prescription for a more distributed, resilient energy system derived directly from the experience of the 1977 blackout, and the subsequent move toward small-scale generation and transmission over shorter distances partly reflects the realization that even massive grid interconnections cannot stave off failures when local generating capacity is inadequate. The two blackouts, moreover, were startling reminders of the magnitude of the responsibility society had handed to the providers of electrical power. They were occasions for some to question whether monopolistic private utility companies -- saddled with massive, expensive equipment and vulnerable interconnections, and lacking market incentives to maintain reliability or affordable rates -- were worthy of that responsibility. The private utility is not an endangered species in the large technological ecosystem; the pastoral visions of windmill-covered fields and photovoltaic-covered roofs evoked by the work of the Lovinses and others are unlikely to materialize anytime soon. But a future in which consumers are less beholden to brittle, oversized, inefficient power systems for the reliable supply of electricity may already be on its way.

The Machine Stops

Go to a quiet hilltop in any city of respectable size, away from distracting noises, and close your eyes. You will hear a constant dull roar that seems to come from all directions. It is the sound of thousands of cars, trucks, motorcycles, airplanes, railroad engines, air conditioners, ventilation fans, radios, stereos, and televisions, all mixed together like the hash of frequencies engineers call "white noise." It is the pulse beat of technological civilization, the rush of energy through a vast artificial bloodstream. It surrounds us all day long, yet we hardly perceive it. We are like Vashti, an inhabitant of the underground city in E.M. Forster's science-fiction short story "The Machine Stops": "Above her, beneath her, and around her, the Machine hummed eternally; she did not notice the noise, for she had been born with it in her ears."[110]

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[109] Hirsh, *Technology and Transformation in the American Utility Industry*, 157-70.

My point, and Forster's and Heidegger's, is that we usually fail to see what is going on all around us until some disaster forces a break with our expectations. When the Machine finally stops -- sending an airship crashing through her underground complex -- Vashti dies in the rubble, but lesser calamities may suffice to remind us of our own technological dependence. Power failures are among the most common of such reminders. Once a blackout has occurred it is usually too late to prevent harm and disruption, but such events can also be the beginning of a process of investigation, thought, and political experimentation. As noted by the writers of a 1989 *NOVA* episode on New York City and the technologies like water, sewers, and electricity that keep it running, "It's an interesting thing about these systems: they're pretty much invisible, and pretty much ignored, until they break down. And of course they break down, especially when they're ignored.

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[110] E.M. Forster, "The Machine Stops," in Ben Bova, ed., *The Science Fiction Hall of Fame, Volume IIB* (New York: Avon, 1973) 248-79; originally published in E.M. Forster, *The Eternal Moment and Other Stories* (New York: Harcourt Brace Jovanovich, 1928).

It's a vicious circle, really. But given a little public insight, not inevitably so."[111]

The 1965 and 1977 blackouts did not inspire grassroots squadrons to question Consolidated Edison's competence or the wisdom of interconnecting electrical utilities from Lousiana to Québec. Though the political clashes during the nineteen-sixties and seventies between advocates of public and private power need more study, it does not seem that the blackouts changed the balance in this struggle significantly. Nor did the expanding environmental lobby (which will play an important role in each of the next three chapters) perceive electric system reliability as an issue demanding its attention, except on the level of community opposition to the construction of individual plants or transmission lines. What the blackouts *did* do, mainly, was force everyone affected by them to recognize the power grid's fallibility -- and perhaps to ponder what this fallibility means in a world where every act from microwaving one's dinner to preventing an inadvertent nuclear war depends on the smooth functioning of large, complex technological systems. After the 1977 blackout, it was John Noble Wilford, director of science news for the *New York Times*, who penetrated to the heart of the matter:

> When the lights go out, as they did in New York last week, people suddenly realize how dependent they are on electricity for the amenities and necessities of life. And they must wonder if the blackout, temporary though it was, does not represent yet another warning that, as Emerson once wrote, 'Things are in the saddle and ride mankind.'...[But] Emerson could not have imagined the 'things' of today's plugged-in society or the magnitude of the disturbing questions raised anew by the blackout. Will Americans have to learn to live with less speed and fewer conveniences, and like it? Are the technologies that sustain modern life too complex

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[111] Carl Charlson, writer and producer, "The Hidden City," *NOVA* episode #1611 (Boston: WGBH Educational Foundation, 1989). The "public insight" called for in this passage might involve closer, more sophisticated oversight of the municipal and private bureaucracies that provide essential services, and a willingness to pay for improved maintenance and preventive measures.

> to manage? How many blackouts, oil embargoes and other alarms must be endured before the nation and the world find a way out of the energy crisis?[112]

As long as someone is writing such words, 'things' are not entirely in the saddle. The real value of technological disasters is that they give people pause to reassess their technological surroundings. But only if sufficient numbers of those affected choose to remember their experiences and resist an automatic return to tradition -- as occurred after the Three Mile Island disaster, described next -- can there be any possibility of democratic change in society's technological arrangements. The answers are not in the newspapers: only the questions.

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[112] John Noble Wilford, "The 'Good Life' Has Found a Limit," *The New York Times* (July 17, 1977) section 4, page 1.

Chapter 3

THE BILLION-DOLLAR MAUSOLEUM

Three Mile Island and the Slow Demise of Commercial Nuclear Power

Hell no, we won't glow.
— anti-nuclear slogan
chanted by protesters at
Three Mile Island[1]

The core of the Unit 2 reactor at Three Mile Island is a strange, dark, forgotten world. A void fills the center of the vessel where 40,000 pounds of molten uranium fuel burned through the reactor's inner wall fifteen years ago and slumped down into its bowl-shaped bottom. The thirty feet of water now covering the melted fuel is kept at a sub-tropical 80° Fahrenheit by the fuel's ongoing radioactive decay. Eddies and convection currents swirl through the blackened water, in which are suspended fine sediments and the decomposing remains of several hardy species of algae, fungi, and bacteria which once flourished under the hot camera lights used during the delicate defueling operation. Most of the fuel has long since been broken into bits and removed, a pebble at a time, by workers who used chisels and pliers attached to 40-foot-long metal poles. The workers were allowed to spend no more than 20 hours every six weeks inside the containment building, and their task took almost a decade to complete. Even so, much of the radioactive debris is still there. It has been burrowed through like Swiss cheese, so that no more than 70 kilograms, the critical mass required to initiate a fission chain reaction, is present in any single "neutronic area." According to plant owner General Public Utilities, which has already spent $1 billion on the cleanup operation, the reactor is in "Post Defueling Monitored Storage" -- meaning that the rest of the job will be put off until the entire plant reaches the end of its commissioned lifetime around the year 2010.[2]

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[1] Richard D. Lyons, "Antinuclear Politicking Makes Odd Bedfellows," *The New York Times* (May 13, 1979) 2E.

Three Mile Island is still an operating nuclear power facility, feeding a peak 906 megawatts of electricity to the surrounding grid. The Unit 1 reactor, which began commercial service in 1974, was undamaged by the meltdown at the newer Unit 2. It sat idle for seven years after the accident while, outside the plant gates, citizens and regulators battled over its future. But in October 1986, the battle decided in its favor, Unit 1 was restarted without trouble. The hundreds of fuel assemblies in its core -- each a 12-foot stack of inch-long uranium oxide pellets, covered by a zirconium alloy cladding -- continue to radiate the fast neutrons which, when slowed by water in the primary cooling system, become slow enough to knock other neutrons off of other splitting bits of uranium in a self-sustaining reaction. The highly pressurized water in the primary cooling system carries the 575° F heat liberated by this fission reaction to the steam generator. There, the primary cooling system gives up heat to a separate, "secondary" cooling system, creating the steam used to run the huge turbines in the generator building. The 110 commercial nuclear reactors still operating in the United States, most of them light-water reactors (LWRs) like those at Three Mile Island, together produce about 20 percent of the United States' electricity supply.

The proximity of the operating Unit 1 reactor to its ruined counterpart only a hundred yards away is symbolic of larger contrasts. For most Americans, the words "Three Mile Island" connote a set of menacing television images: panic, confusion, evacuation, the huge cooling towers looming over communities threatened by invisible radiation. But Three

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[2] William Booth, "Postmortem on Three Mile Island," *Science* (vol. 238, Dec. 4, 1987) 1342-45.

Mile Island is also a real place where thousands of people still work, visit, or live nearby, and where the consequences of the partial meltdown on March 28, 1979, are still felt in the form of health worries, higher utility rates, and lingering bitterness.

Unit 2 is also a metaphorical mausoleum for the dying hopes of the nuclear industry and its government proponents. These groups once envisioned nuclear power as a safe source of electricity "too cheap to meter" but now preside over a technology which, for political and economic reasons stemming largely from the accident itself, is slowly going extinct.[3] No new nuclear plants have been ordered in the U.S. since 1978, more than a hundred have been cancelled, and many plants are approaching the end of their useful lifetimes. Alvin Weinberg, one of the inventors of the LWR, predicted in 1979 that "unless the public can regain confidence in nuclear energy, the nuclear age will grind to a halt as the present reactors run their course," and this is more or less what is happening.[4]

But the continuing operation of TMI Unit 1, despite strong opposition, testifies to the industry's grip on life. Nuclear power's public reputation was largely undone by the Three Mile Island accident, subsequent revelations of operator incompetence and safety violations, and the 1986 Chernobyl disaster (see Chapter 5), but the industry remains a pervasive presence in American society. No location on the eastern seaboard between Maine and South Carolina, save portions of Delaware and eastern Maryland, is more than 50 miles from an operating nuclear reactor. Altogether more than 10 million Americans live within 20 miles of a nuclear plant, and more than 20 million live within 30 miles.[5]

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[3] Atomic Energy Commission chairman Lewis Strauss included the now-famous line "It is not to much to expect that our children will enjoy in their homes electrical energy too cheap to meter...This is the forecast for an age of peace," in a speech to the National Association of Science Writers in September, 1954. Quoted in Daniel Ford, *The Cult of the Atom* (New York: Simon and Schuster, 1982) 50.

[4] David Burnham, "Three Mile Island Accident: A Cloud Over Atom Power," *The New York Times* (Sep. 23, 1979) 1, 48.

The twin TMI reactors, one thriving, one silent, embody the complex history of nuclear energy itself. If any nuclear plant should have been an easy target for shutdown by local opponents, it is Three Mile Island. The meltdown was, after all, the closest the U.S. nuclear industry has come to a worst-case accident. But once the industry and the Nuclear Regulatory Commission closed ranks to ensure that Unit 1 would be restarted, it became clear that the regulatory and business structures governing nuclear power in the United States excluded direct involvement by local citizens. Area residents' seven-year fight to override those processes ended in defeat, and every glimpse of the plant's 350-foot cooling towers now reminds them of the possibility -- however remote -- that a similar or worse accident could happen again.

The world beyond the TMI region, however, has become a very different place since the accident. The meltdown so magnified the regulatory, financial, and political burdens associated with nuclear power that utilities and their investors no longer consider it a viable way to meet future energy needs. (Energy suppliers have turned instead to demand management and the idea of "distributed generation," described in Chapter 2.) This is not to claim that nuclear power is dead; the last LWR will not be decommissioned until sometime around 2025. But changes vital to the long-term survival of the industry have not yet taken place. In the years since Three Mile Island, many existing LWRs could have been phased out while a new generation of safer reactors was under development; instead, "inherently safe" nuclear reactors are still decades away from commercial deployment. A safe, acceptable location could have been found for the temporary or permanent disposal of spent reactor fuel and other radioactive wastes; instead, controversy and scientific uncertainty continue to thwart the search for such a hiding-place. Given the added onus of the Chernobyl disaster in 1986, it seems unlikely that the percentage of the public favoring the construction of more nuclear plants will ever return to pre-TMI levels. U.S. Energy Secretary Hazel O'Leary, moreover, has declared the government's official lack of interest in pursuing new fission technologies.

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[5] David Burnham, "Siting Nuclear Reactors Once Seemed Simple and Safe," *The New York Times* (May 6, 1979) E 6-8 (see accompanying maps).

Why these disparate, almost paradoxical outcomes? How could the U.S. antinuclear movement have failed to shut the single most demonstrably hazardous plant in the country, while at the same time the accident has helped impose a not-so-distant limit on commercial nuclear power's lifespan? The answer has partly to do with the difference between local and national responses to disaster. "Lose locally, win globally" is a common pattern in the stories told in this thesis. At the local level, even the best-organized and most strongly-supported citizens' groups face uncertain odds when they confront large industries and government bureaucracies. In their struggle to win technological change to reduce the risk of a future catastrophe, citizens often become entangled in side disputes over legal and economic issues; their organizations often succumb to internal disputes; they are often simply outspent or cut out of negotiations by influential industry groups. At the national level, however, industries usually have a harder time maneuvering around broad-based shifts in public opinion. Investor edginess, boycotts, state ballot initiatives, new federal legislation and the like have top-down effects that are difficult for even big companies to ignore.

Breakdowns severe enough to merit national attention are almost always greeted first by vigorous local protest movements. The irony is that few of the significant technological and political changes that emerge from these disasters directly answer local citizens' concerns -- and almost never do they adequately compensate survivors for their trauma. To put this more positively, a community's victimization in a severe breakdown may inspire sympathy, outrage, and concern on a broad enough scale that society-wide changes occur to prevent a recurrence in *any* location.

The Three Mile Island accident has become, in many respects, the archetypal American technological disaster. Though other accidents have cost more lives, TMI occupies a special place in the iconography of technics-out-of-control, to use Winner's apt phrase.[6] Why else would some 80,000 curious tourists each year take time to visit the facility? Why else would Homer Simpson, patriarch of the popular TV family, be portrayed as a bumbling nuclear-plant operator who catches three-eyed fish in the cooling pond and averts a meltdown at the last second by playing eeny-meeny-miney-moe with the control panel? When an industry that was once a symbol of the nation's technological prowess becomes the butt of jokes among its own citizens, fundamental changes are underway, and I will use this chapter to explore the technological and political events underpinning these changes.

Because the events at Three Mile Island were so central to Americans' disillusionment with nuclear power, they are examined here in detail, beginning with an account of the military origins of light water reactors and the politics surrounding the early days of the nuclear enterprise. The chapter highlights the aspects of the accident that most alarmed the public and provided powerful ammunition for nuclear power's critics. I then recount the struggle over the restart of the Unit 1 reactor and examine its implications for the democratic control of large technological systems. Finally, I trace the declining fortunes of the U.S. nuclear industry since Three Mile Island, stressing the role of public opinion as measured by state ballot measures and surveys.

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[6] See Langdon Winner, *Autonomous Technology: Technics-Out-Of-Control as a Theme in Political Thought* (Cambridge: MIT Press, 1977).

The Cold War's LWR Legacy

The accident at Three Mile Island punctured a quarter-century's claims for the safety and efficiency of nuclear power in the United States. In official risk-assessment reports nuclear engineers had pegged the probability of a TMI-type accident at once in every 17,000 years of a reactor's operation -- a prediction so roseate that critical valves and indicators whose failure led directly to the meltdown had been designated by the Nuclear Regulatory Commission as "non-safety-related."[7] Power plant operators and regulators, not to mention the people of Pennsylvania, realized in retrospect how lucky they had been that the first major core-melt accident to strike the U.S. nuclear industry -- the failure that finally exposed the weaknesses of the system -- had caused no casualties. As it was, the accident caused widespread panic, the release of small amounts of radiation into the atmosphere, billions of dollars in damage to the plant, and the near financial ruin of the utility operating it.

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[7] From the so-called Rasmussen Report of 1975, chaired by MIT Professor of Nuclear Engineering Norman Rasmussen. See U.S. Nuclear Regulatory Commission, *Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants,* NUREG-75/014, WASH-1400 (Washington, D.C.: Government Printing Office, 1975). A reactor-year is equivalent to the full-time operation of a nuclear reactor for one year; the U.S. nuclear industry has less than 3,000 reactor-years of operating experience behind it. For a pointed critique of probabilistic risk assessment methods, see "Nuclear Power: Can We Live With It? A Panel Discussion on Nuclear Risk, the Lessons of Three Mile Island, and the Future of Nuclear Power," *Technology Review* (June/July 1979) 33-36.

Robert Kates, a geographer at Clark University who was part of a team in the nineteen-seventies investigating the possible outcomes of hypothetical nuclear accidents, described his group's conclusions to newspapers shortly after Three Mile Island: "If the first accident were a real disaster involving loss of life and extensive contamination, we felt, it would spell the end [of nuclear power]. But if the first incident were moderate and handled very smoothly, public anxiety would decrease." TMI fell squarely in between these two projections. As the nuclear lobby repeated mantra-like after the accident, no one died at Three Mile Island, but even proponents of nuclear power had to admit that the way experts and utility officials handled the accident was far from smooth. "The stage may be set," Kates ventured, "for what is an exceedingly rare event in our society: the rejection of a technology."[8]

"Cautious disinvestment" is a better description than "rejection" for what has actually happened since Three Mile Island. If the hopes tied to commercial nuclear power over its 30-year history could be graphed, TMI would mark the midpoint on an arching curve that has been descending ever since. The first, upward half of that curve -- especially the buoyant early years when the military, utility companies, and reactor manufacturers like General Electric and Westinghouse were in league to promote the "peaceful atom" -- is where we must look for many of the political and technological decisions that made the accident possible and that virtually assured that Americans would, sooner or later, turn against nuclear power.

Though the first atomic bombs were built in utmost secrecy, the new force unleashed over Hiroshima and Nagasaki in 1945 did not take the globe entirely by surprise. The physical principle behind both atomic weapons and atomic power had been set down by Albert Einstein in 1905 in his famous equation $E=mc^2$, which accounted for the odd fact that when a heavy atomic nucleus splits into two smaller nuclei, their combined masses are less than that of the original nucleus. The missing mass, Einstein showed, is liberated as energy in the form of heat and gamma rays. The ever-prescient H.G. Wells mused about atomic chain reactions and coined the term "atomic bomb" in his 1913 novel of global air warfare, *The World Set Free*. In 1933 the Hungarian physicist Leo Szilard, while waiting on a London pavement for a traffic signal to change colors, had a sudden vision of how to initiate a fission chain reaction by starting with extremely heavy, unstable elements like uranium. A series of well-publicized experiments in the late 1930s demonstrated the feasibility of Szilard's idea. The result -- to condense a story others have explored in great detail[9] -- was the Manhattan Project.

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[8] David F. Salisbury, "How will public take its jarring encounter with A-power risks?" *The Christian Science Monitor* (April 5, 1979) 1, 7.

The war's end left the United States with sole control over nuclear energy, and Congress moved quickly to preserve this psychological and strategic advantage. The Atomic Energy Act of 1946 -- a response, in part, to the concerns of Manhattan Project scientists and others that they had unleashed an energy source that could be used for great evil -- put nuclear technology under civilian control on the principle that only in this way would its peacetime potential be fully exploited and the horrors of Hiroshima and Nagasaki, if this were possible, begin to be redeemed. In practice, however, the new Atomic Energy Commission (AEC) was handmaid to the military, making bombs to its specifications, maintaining tight government control over fissionable materials and bomb-building knowledge, and managing the network of laboratories and factories left behind by the

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[9] See especially Richard Rhodes, *The Making of the Atomic Bomb* (New York: Simon & Schuster, 1986).

Manhattan Project. In 1954 -- five years after Russia had broken the U.S. nuclear monopoly, and shortly after President Eisenhower's "Atoms for Peace" speech at the United Nations -- the Atomic Energy Act was amended to allow private companies to pursue the development of controlled fission power. The amendments provided for private ownership of nuclear reactors, private control of fissionable materials, and private access to government nuclear secrets.[10]

Eisenhower had told the UN General Assembly, "It is not enough to take this weapon out of the hands of the soldiers. It must be put into the hands of those who will know how to strip its military casing, and adapt it to the arts of peace."[11] The first commercial venture in controlled nuclear fission, however, was a thoroughly military affair, down to the choice of reactor technology. The successful launch in 1954 of the U.S.S. *Nautilus*, named for Captain Nemo's wondrous vessel, had proved that the pressurized light-water reactor developed by Alvin Weinberg and others at Tennessee's Oak Ridge National Laboratory could be squeezed into a submarine; now the *Nautilus*' builder, Hyman G. Rickover, was seconded to Shippingport, Pennsylvania, to help the Westinghouse Corporation build an LWR on the banks of the Ohio River. (Federal leadership and large subsidies were required to promote civilian nuclear power, historian Brian Balogh explains, because private companies feared the technology would be unprofitable.[12]) Because light-water reactors require so much complex, corrosion-prone plumbing, many AEC scientists favored other approaches to moderating and cooling the fission reaction, such as graphite-moderated/gas-cooled or heavy-water-moderated/heavy-water-cooled reactors.[13] But LWR technology was ready first, and the AEC feared that any delay would risk ceding the U.S. lead in fission power to the Soviets, who might then gain a major influence over the developing world. "In essence," as one industry observer put it, "the nuclear submarine reactor was beached and scaled up by the private sector at the urging of the AEC."[14] Under Rickover's leadership, the Shippingport plant was completed in under three years, opening in 1957.

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[10] See Richard G. Hewlett, et al., *A History of the United States Atomic Energy Commission*, 3 vols. (University Park, Penn.: Pennsylvania State University Press, 1962-).

[11] Eisenhower spoke at the United Nations in December, 1953. Quoted in U.S. President's Commission on the Accident at Three Mile Island, *Report of the Office of Chief Counsel on the Nuclear Regulatory Commission* (Washington, D.C., Oct. 1979) 6.

[12] Brian Balogh, *Chain Reaction: Expert Debate and Public Participation in American Commercial Nuclear Power, 1945-1975* (Cambridge, U.K.: Cambridge University Press, 1991) 95-119.

The possibility of a dangerous heat buildup inside the core of a light-water reactor was always implicit in the notion of "controlled" nuclear fission. Reactor fuel rods must be continuously bathed in high-pressure coolant water to remove both the heat generated by fission and heat from the fuel's normal radioactive decay; if the coolant flow stops, even the insertion of the graphite control rods (a reactor "scram," halting the fission chain reaction[15]) is not enough to contain the decay heat. Unless emergency systems inject extra coolant, a core meltdown is the inevitable result. Congress, for its part, neglected safety questions in both the original Atomic Energy Act and the 1954 amendments.[16] Private industry was more jittery. A 1957 AEC study entitled "Theoretical Possibilities and Consequences of Major

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[13] Balogh writes, "Because the pressurized water reactor (PWR) at Shippingport would do little to advance scientific knowledge or improve nuclear power's economic competitiveness, advocates of more sophisticated approaches dubbed the PWR "Power Without Reason." *Chain Reaction*, 107.

[14] Edward J. Walsh, *Democracy in the Shadows: Citizen Mobilization in the Wake of the Accident at Three Mile Island* (New York: Greenwood Press, 1988) 23.

[15] The phrase is a not-so-quaint relic of the early days of controlled chain-reaction experiments, when the most basic safety measure was to "drop the control rods and scram."

[16] Except for orders that the AEC "protect health and minimize danger to life and property" by preventing the diversion or loss of nuclear material. *Report of the Office of Chief Counsel on the Nuclear Regulatory Commission* , 7.

Accidents in Large Nuclear Power Plants" (also known by its publication number, WASH-740) predicted that a worst-case reactor breach would kill 3,400 people, injure 43,000, and spread radioactivity over a 150,000-square-mile area, causing $7 billion in damage.

Before they would sink significant sums into nuclear energy, utility companies demanded federal protection against such fantastically high potential liability. Congress, just as eager as the AEC to promote nuclear power, complied. "My gosh," one resident of the Three Mile Island area would later exclaim, "the federal government is going to subsidize a nuclear disaster!" -- a comment which more or less sums up the intent of the Price-Anderson Act of 1957.[17] The law limited total damages available to the victims of a nuclear accident to $560 million. The first $60 million would be paid by the industry's private insurers, with the rest to be underwritten by the United States Treasury.[18] Without this benevolent intervention by Congress, the usual market mechanisms for weighing potential profit and loss would never have favored nuclear energy.

As regulated monopolies, utilities in the United States have traditionally operated on a "cost-plus" basis, meaning that a company's rates can legally be set high enough to ensure profits no matter how large its capitalization or operating costs.[19] During the nineteen-sixties this fact, along with the cushion provided by the Price-Anderson Act, made the construction of nuclear plants virtually risk-free for investors. In 1962 there were four operating reactors in the United States, each with an electrical output of about 150 megawatts, but in 1965 alone the AEC issued construction licenses for 30 new reactors.[20]

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[17] Quoted in Raymond L. Goldsteen and John K. Schorr, *Demanding Democracy After Three Mile Island* (Gainesville: University of Florida Press, 1991) 141.

[18] Amendments made to the Price-Anderson Act when it was renewed in 1988 limit the maximum liability of the nuclear industry to $7 billion, or about $63 million per plant, with Congress retaining discretion to pay for damages above this amount. The Act will expire in 2002 unless renewed again. See National Research Council, *Nuclear Power: Technical and Institutional Options for the Future* , 43.

[19] This has begun to change in the nineteen-eighties and nineties; utilities are no longer so quick to pass cost overruns on large construction projects on to ratepayers, and the California Public Utility Commission's decision to allow utility competition in the state may have far-reaching effects on profitability. See chapter 2.

At the time, oil and other competing energy sources were cheap and interest rates were rising, considerations that sparked a menacing new trend: the attempt to realize economies of scale by wringing more power from reactor cores. Designers planned larger, more efficient plants with electrical outputs of up to 1,200 megawatts, five to seven times greater than that of the first-generation LWRs. But this scaling-up required that the reactor cores be surrounded with complex emergency cooling machinery, reducing the reaction time available to operators in the event of an accident. This problem in turn required the construction of elaborate backup systems -- the "defense-in-depth" strategy -- which themselves created even more situations in which operators could err. The "race between education and catastrophe" predicted by Wells was playing itself out inside nuclear plants as the complexity of reactor systems began to exceed the comprehension and agility of their operators.

When AEC officials updated the WASH-740 safety report in 1964, they hoped to find that the larger reactors were less capable of causing catastrophic damage than their predecessors. Instead, estimates of the number of people who would be killed in a worst-case accident rose from 3,400 to 45,000, the number injured from 43,000 to 100,000, and the amount of damage from $7 billion to $17 billion. At the request of the Atomic Industrial Forum, an industry trade group, the AEC suppressed the updated report.[21] Plant construction plunged forward. By 1970 the Commission, which had "no intention of seriously constraining the commercial use" of nuclear power, had issued permits for more than 90 large plants.[22]

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[20] Walsh, 24-25.

During the nineteen-sixties the civil rights movement, the women's movement, the anti-war movement, the gay rights movement and the environmental movement finally began to sweep away Americans' old submissiveness toward established institutions and customs.[23] Books like Rachel Carson's *Silent Spring* (1962) and Stewart Udall's *The Quiet Crisis* (1963) were wakening Americans to the extent of their society's environmental depradations. At the same time, international protest over the health effects of fallout from atmospheric atomic weapons testing and the conclusion in 1963 of an above-ground test ban treaty had sensitized people to the issues of airborne radioactivity and the dangers of reactor accidents. It was inevitable that the secretive nuclear industry -- born in the Cold War crucible, nurtured by special government dispensation, and largely sanguine about safety questions -- would eventually run afoul of the nation's emerging environmental consciousness.

Although these were the nuclear industry's boom years, local environmental groups managed to force the cancellation or relocation of several isolated projects. In 1964 New York's Con Ed abandoned plans for a 1,000 megawatt plant at Ravenswood, Queens, a stone's throw from downtown Manhattan, in the face of skepticism over the necessity of placing a nuclear plant in such a densely populated area.[24] Later that year Pacific Gas & Electric Company gave in to local residents who worried that a plant under construction at Bodega Head, California, would be vulnerable to earthquake damage and would blight the area's scenic beauty.[25] In 1968 a plan to use nuclear bombs to blast huge caverns for liquid natural gas storage under the Appalachians -- part of the "Project Plowshares" effort to demonstrate the peaceful uses of atomic explosions -- was dropped due to citizen opposition. In 1969 local residents stopped the construction of a fast breeder reactor planned for a site on the Susquehanna River in Pennsylvania (the same river where the Three Mile Island Unit 1 reactor was under construction). The breeder project was forced to move to Tennessee.[26]

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[21] Walsh writes: "The 1964 [Wash-740 update] was revealed to the Joint Committee on Atomic Energy, the Atomic Industrial Forum, and representatives from reactor manufacturers such as Westinghouse, General Electric, and Babcock & Wilcox. The Atomic Industrial Forum, on behalf of the industry, strongly urged that the revised study not be published or otherwise released to the public. The AEC accepted this recommendation and withheld the WASH-740 update from publication...In response to those seeking information about the updated study, the AEC insisted that it was never completed." *Democracy in the Shadows*, 25. Daniel Ford details this story at greather length in *The Cult of the Atom* (New York: Simon & Schuster, 1982).

[22] *Report of the Office of Chief Counsel on the Nuclear Regulatory Commission* , 12.

[23] In Janet Malcolm's felicitous words, "The nineteenth century came to an end in America only in the nineteen-sixties." "The Silent Woman - I," *The New Yorker* (Aug. 23 and 30, 1993) 89.

Between 1969 and 1971, opposition to nuclear power grew into an authentic national movement. Two widely-read books published in 1969 -- *The Careless Atom,* by Sheldon Novick, and *Perils of the Peaceful Atom,* by Richard Curtis and Elizabeth Hogan -- incensed industry and AEC officials with their depictions of the horrors of a nuclear accident. Anti-nuclear groups gained the legal ammunition with which to delay dozens of projects when, in 1971, the federal courts ruled in the Calvert Cliffs decision that the National Environmental Policy Act of 1969 required the AEC to evaluate the environmental impacts of nuclear plants before it could grant construction permits. (The ruling also forced the AEC to re-license the 60 plants already in operation, contributing to extensive delays throughout the industry.)

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[24] See George T. Mazuzar, "A Power Reactor for New York City," *Technology and Culture* (April, 1986).

[25] J. Samuel Walker, *Containing the Atom: Nuclear Regulation in a Changing Environment, 1963-1971* (Berkeley: University of California Press, 1992) 59-72, 84-99, 388-389.

[26] Walsh, 29-30.

Also in 1970, the Union of Concerned Scientists (UCS) stirred interest in reactor safety by publishing a sharp critique of the AEC's technical standards for LWR emergency core cooling systems. Founded in 1969 by a group of MIT professors opposed to the nuclear arms race and U.S. military policies in Vietnam, UCS had recently turned its expert lens on environmental issues, including nuclear power. The group's study concluded that the emergency cooling systems were "likely to fail" in the event of a reactor coolant leak, leading to "a peace-time catastrophe whose scale...might well exceed anything the nation has ever known."[27] UCS called on the AEC to stop issuing operating licenses until the problem could be solved. In a petition circulated in 1975, the group recommended "a drastic reduction in new nuclear power plant construction starts before major progress is achieved in the required research and in resolving present controversies about safety, waste disposal, and plutonium safeguards."[28]

If nuclear power had "come of age" during the nineteen-sixties, to use the words of AEC Chairman Glenn Seaborg, then by the middle nineteen-seventies it was already showing signs of decrepitude.[29] The number of citizens who said they would oppose the construction of a nuclear plant near their homes had risen from between 3 and 8 percent in 1965 to between 30 and 38 percent in 1971, prompting some utilities to build conventional power plants rather than face public protest and protracted licensing disputes.[30] In 1973 environmentalists threatening a suit against the AEC under the Freedom of Information Act finally forced the release of the updated WASH-740 accident predictions, a public-relations disaster for the industry. Technical and economic difficulties heightened uncertainty among utilities and investors. Several years before the accident at TMI confirmed the trend, orders for new nuclear plants had begun to fall off drastically; some 231 reactors were ordered through 1974, and only 15 after that.[31] Conservation measures inspired by the the 1973 Arab oil embargo had moderated the growth of electrical demand, making it harder to justify the enormous investment required to bring a nuclear plant on-line. Construction delays, the result of environmentalist intervention, labor trouble, tightening regulations, and bureaucratic backlogs at the AEC, plagued the industry.[32] Delays translated into huge cost increases through accumulating interest charges. Operators, moreover, were having difficulty coaxing their plants to perform up to specifications. The nation's nuclear plants were off-line for maintenance, repairs, or refueling for an average of more than four days out of ten, a dismal rate compared to plants in France, Japan, and West Germany.[33]

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[27] Quoted in Walker, 199.

[28] Quoted in Allan Mazur, "Three Mile Island and the Scientific Community," in Thomas Moss and David Sills, eds., *The Three Mile Island Nuclear Accident: Lessons and Implications* (New York: The New York Academy of Sciences, 1981) 216.

[29] Glenn T. Seaborg, "Peaceful Uses of Atomic Energy," excerpted from the Third United Nations International Conference on the Peaceful Uses of Atomic Energy at Geneva, in Harlow Shapley, et al., eds., *The New Treasury of Science* (New York: Grolier, Inc., 1965) 325.

In 1974 -- the same year construction was completed on the Unit 1 reactor at Three Mile Island -- Congress split apart the AEC in an attempt to sort out the agency's promotional and regulatory roles. In retrospect, it would have been surprising if the Cold War preoccupation with strength-at-any-cost that governed the AEC's primary task of bomb-building had not also influenced its civilian programs; had not led it to peddle a flawed reactor technology simply because it was the first one available; had not fostered an indulgent disregard toward the industry's safety shortcuts. Congress, by delegating weapons production and reactor development to the new Energy Research and Development Agency (later the Department of Energy) and vesting oversight of the nuclear power industry in the Nuclear Regulatory Commission, hoped to mollify grassroots groups critical of the plant-siting and licensing process. The Reorganization Act undid itself, however, by transferring the AEC's regulatory bureaucracy of some 2,000 people -- intact and "fully conditioned to overlooking or neglecting difficult questions"-- to the new NRC.[34] Within five years, the President's Commission on the Accident at Three Mile Island would describe the NRC as an agency where the promotional philosophy was still so rampant, and safety standards so slipshod, that an entirely new restructuring was needed.[35]

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[30] Walker, 391, 408-409. These poll results, like all the "social-science" statistics used this thesis, should be interpreted only as loose indicators of ebb and flow of public opinion. Survey results are highly sensitive to small changes in the wording of questions, among other factors, and in any case citizens' actual beliefs are only weakly mirrored in their responses to these selected, standardized inquiries.

[31] John L. Campbell, *Collapse of an Industry: Nuclear Power and the Contradictions of U.S. Policy* (Ithaca: Cornell University Press, 1988) 3.

[32] Walker, 409.

[33] National Research Council, *Nuclear Power: Technical and Institutional Options for the Future*, 182.

Had the accident at Three Mile Island never happened, regulators, reactor manufacturers, and utilities might or might not have gone forward with plans to convert more and more of the United States' electrical supply to LWR generation; counterfactual questions are the hardest for historians to answer. But on the eve of the disaster the public's doubts about nuclear power were clearly stronger than ever before. At the Seabrook construction site in New Hampshire, thousands had recently taken part in the largest anti-nuclear demonstrations to date. The NRC, under pressure from environmental groups, had just shut down five East Coast reactors thought vulnerable to earthquakes. And from the long lines outside theaters showing *The China Syndrome,* released in mid-March, 1979, it appeared that audiences found the film's fictional reactor-accident scenario all too plausible. (In one of the more bizarre instances of art anticipating life, a physicist in the film put the AEC's own WASH-740 predictions into prosaic terms, explaining that a loss-of-coolant accident and the resulting meltdown could "render an area the size of Pennsylvania permanently uninhabitable.")[36] The Three Mile Island accident, to quote one industry journal's rueful account, "could not have come at a better time for opponents of nuclear power."[37]

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[34] Brightsen, "The Way to Save Nuclear Power," *Fortune* (Sept. 10, 1979) 128.

[35] U.S. President's Commission on the Accident at Three Mile Island, *The Need for Change: The Legacy of TMI* (Washington, D.C.: Government Printing Office, Oct. 1979) 19-22, 61-67.

"The Thing Was Simply Uncorked"

The following inquest does not scrutinize every human error or mechanical or electronic failure that contributed to the crisis at Three Mile Island. The need is to isolate the parts of the event that, in retrospect, seem to have decisively shaped public opinion regarding nuclear power. Fine-grained, technically exhaustive accounts of the accident have been available from soon after the disaster.[38] But it appears that several dramatic moments revealed how the nuclear industry operated under pressure and convinced many lay people that the hazards associated with LWRs outweighed the benefits. There were encouraging moments in the crisis, for example the times when technicians took actions that prevented an even worse accident or when public servants brought needed calm to a chaotic situation. But the close calls and last-minute saves made less impression than the series of things that went wrong. The accident's technical causes and the impressions they left on the public make the disaster's political aftermath intelligible.

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[36] The China Syndrome's screenwriter, Mike Gray, consulted with MIT physicist and Union of Concerned Scientists founder Henry Kendall while preparing the screenplay. Kendall wrote in 1980, "The risks of catastrophic [nuclear] accidents has been extensively studied by scientists...These accidents, which could disperse massive amounts of radioactivity from a nuclear power plant into the surrounding area, have not arisen to date in the country's limited commercial nuclear power experience, but the long-term chances of operating nuclear plants while avoiding such potential calamities remain an open question." Henry W. Kendall and Steven J. Nadis, eds., *Energy Strategies: Toward A Solar Future* (Cambridge, Mass.: Ballinger Publishing Co., 1980) 11. See also Union of Concerned Scientists, *The Risks of Nuclear Power Reactors* (Cambridge, Mass.: Union of Concerned Scientists, 1977).

[37] "Accident clouds future for U.S. nuclear power," *Chemical & Engineering News* (April 9, 1979) 8.

[38] See footnote 43.

To say that the Unit 2 reactor at Three Mile Island was an accident waiting to happen sounds like a cliché, but in fact the partial meltdown occurred so early in the reactor's commercial lifetime and was so heavily foreshadowed by the plant's construction and operating record that the reactor's entire history can be considered ill-starred. Ironically, there was little need for an additional reactor at Three Mile Island; Unit 1 was expected to meet projected demand in the area well into the future. Plant owner General Public Utilities (GPU) had originally intended to build a new reactor at Oyster Creek, New Jersey, but encountered labor problems and licensing delays there and settled on TMI instead.[39] While Unit 1 had performed at or near expected capacity over most of its five-year lifetime, its younger sibling was troublesome from the very beginning. Both Unit 1 and Unit 2 were designed by the Virginia engineering firm of Babcock & Wilcox, but because GPU contracted with different groups of architect-engineers for the installation of the two reactors, they were configured quite differently. The lack of standardization is a major problem throughout the U.S. nuclear industry; each new plant was essentially custom-built. At least one analyst contends that this has been the cause of the industry's downfall.[40] Construction site security at TMI-2 was violated repeatedly between 1974 and 1978. Maintenance crews had been reduced due to cost cutbacks and the remaining crews were seriously overworked. When the NRC granted TMI-2 its operating license on February 8, 1978, there were still 14 "unresolved safety items" on its agenda, including a lack of data on operators' ability to counteract hypothetical pipe breaks and resulting coolant losses.[41] One of the NRC's five commissioners, Richard Kennedy, said later that the plant should not have been operating while these safety matters were still outstanding.[42]

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[39] John Sorensen, et al., *Impacts of Hazardous Technology: The Psycho-Social Effects of Restarting TMI-1* (Albany: State University of New York Press, 1987) 8.

From the time it "went critical" on March 28, 1978, to December 30, 1978, when it started producing electricity, Unit 2 was shut down for adjustments and repairs 71 percent of the time, 30 percent above the industry norm for the startup phase. In one test during startup, a critical safety valve attached to the pressurizer (the vessel that maintains high water pressure in the primary coolant system) had stuck open, creating the possibility of a loss of coolant in the core. (See Item no. 7 in Figure 3.1.) Damage to the reactor was averted, but this power-operated or "pilot-operated" relief valve (PORV) remained leaky even after the plant went on-line. Between December 30 and the day of the accident three months later, the reactor operated at full power less than half of the time.

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[40] Campbell, *Collapse of an Industry*, 31-49.

[41] Sharon M. Friedman, "Blueprint for Breakdown: Three Mile Island and the Media Before the Accident," *Journal of Communication* (Spring, 1981) 125-126.

[42] *Report of the Office of Chief Counsel on the Nuclear Regulatory Commission* , 31.

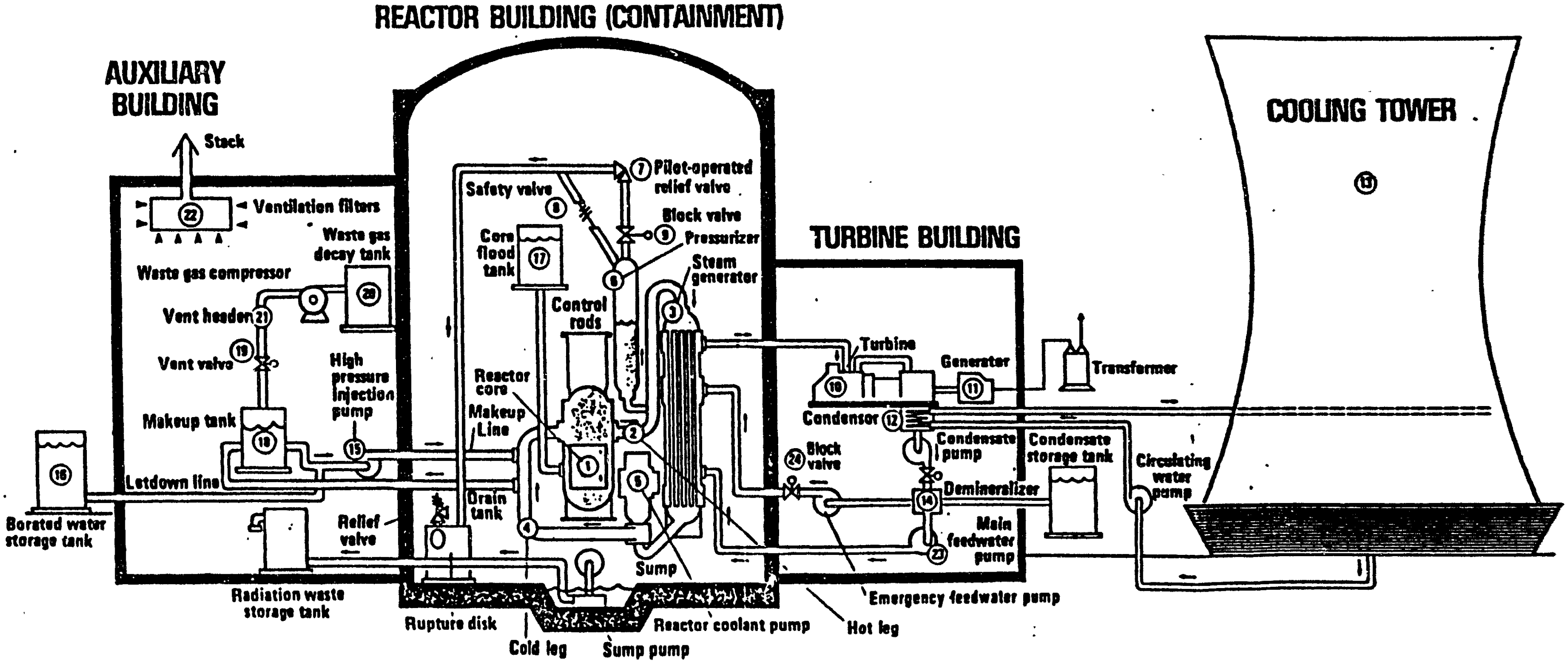
REACTOR BUILDING (CONTAINMENT)
AUXILIARY BUILDING
Stack
22
Ventilation filters
Waste gas decay tank
20
Waste gas compressor
Vent header 21
19
Vent valve
High pressure injection pump
Makeup tank
18
15
16
Letdown line
Borated water storage tank
Relief valve
Radiation waste storage tank
Rupture disk
Cold leg
Sump pump
Reactor coolant pump
Hot leg
Emergency feedwater pump
Sump
5
4
Drain tank
Makeup Line
Reactor core
1
2
Control rods
Core flood tank
17
Safety valve
8
7 Pilot-operated relief valve
Block valve
9 Pressurizer
6
Steam generator
3
TURBINE BUILDING
Turbine
10
Generator
11
Transformer
Condensor 12
24 Block valve
Condensate pump
Condensate storage tank
Demineralizer
14
Main feedwater pump
23
Circulating water pump
COOLING TOWER
13

Fig. 3.1: Three Mile Island Unit 2 Reactor Schematic

(Source: Nuclear Regulatory Commission Special Inquiry Group, *Three Mile Island: A Report to the Commissioners and to the Public*, p. 12.)

The accident began, broadly speaking, with a minor error that had most likely occurred two days before the onset of the actual core-melt emergency.[43] On March 26, 1979, in order to carry out a routine test of the emergency feedwater pumps (designed to inject large amounts of cold water into the steam generator in the event of a loss of circulation in the secondary coolingsystem), operators closed two valves that isolated the emergency feedwater system from the secondary cooling system. After the test, the valves were left closed, although workers swore they remembered having reopened them. Testimony before the President's Commission revealed that "with hundreds of valves being opened and closed in a nuclear plant, it [was] not unusual to find some in the wrong position...Large valves do not close by themselves, so someone must have goofed."[44] One of the two indicator lights in the main control room that would have alerted operators to the valves' closure was obscured by a yellow repair tag hanging down from a different light.[45]

This valve problem is worth mentioning because it was *not* the sort of failure that stirred deep public doubts about LWRs' reliability. It *was* indicative of lax safety training and poor maintenance procedures, but on the whole the public understands the fragility of complex machinery and almost expects a certain level of failure. (Who, for example, would not be surprised to drive a car 100,000 miles without a hint of mechanical trouble?) While the TMI accident drew attention to devices that should have been designed better, operators who should have known better, and a regulatory system that was apparently incapable of detecting and correcting these flaws, these were not the failures that truly alarmed accident-watchers. Rather, it was the systemic nature of the breakdown -- the fact that it resulted from the unforgiving, ultimately incomprehensible *complexity* of the technology itself -- that was truly frightening.

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[43] This and the following ten paragraphs draw on a variety of sources, including: U.S. President's Commission on the Accident at Three Mile Island, *The Need for Change: The Legacy of TMI* (also known as the Kemeny Report); Nuclear Regulatory Commission Special Inquiry Group,*Three Mile Island: A Report to the Commissioners and to the Public,* vol. I (Washington, D.C.: Government Printing Office, Jan., 1980) (also known as the Rogovin Report); B. Drummond Ayres, "Three Mile Island: Notes From a Nightmare," *The New York Times* (April 16, 1979) A1, B10; William Booth, "Postmortem on Three Mile Island," *Science* (Dec. 4, 1987) 1342-1345; Leonard Jaffe, "Technical Aspects and Chronology of the Three Mile Island Accident," in Moss and Sills, eds., *The Three Mile Island Nuclear Accident: Lessons and Implications*; Perrow, *Normal Accidents: Living with High-Risk Technologies* (New York: Basic Books, 1984) 15-31.

[44] Perrow, *Normal Accidents*, 19.

[45] It is also possible that the valves were reopened after the test but closed again by operators during the emergency, or that they were closed from control points outside the main control room. U.S. President's Commission on the Accident at Three Mile Island, *The Need for Change: The Legacy of TMI*, 94.

Ezra Pound once wrote that "error is all in the not done," and this is a fit enough description for the main sequence of events that allowed the Unit 2 reactor core to consume itself.[46] It was early in the morning on March 28. TMI-2 was running at 97 percent power. Operators Craig Faust and Edward Frederick were monitoring instruments in the control room, while night shift supervisor William Zewe worked in a glass-enclosed office at the rear of the control room and shift foreman Fred Scheimann was down in the turbine building. All four of these licensed operators were veterans of Rickover's "nuclear Navy."[47] Scheimann was helping two workers who had been attempting for the last 11 hours to unclog a pipe leading to the condensate polisher, a device that scoured mineral contamination from the water in the secondary cooling system (the one, remember, that removes heat from the primary cooling system and supplies steam to the turbines). The polisher had broken down three times in recent months; now workers were using compressed air from instrument air lines to dislodge a debris-packed resin filter inside the polisher.[48] The instrument air was at a lower pressure than the polisher's water stream, and at 4:00 a.m., water entered the air lines. This disabled instruments and shut down the polisher, which in turn triggered the main feedwater pumps and the electrical turbines themselves to trip off. Circulation halted throughout the secondary cooling system, leaving no escape for the tremendous heat being carried away from the reactor core by the primary cooling system.[49]

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[46] Ezra Pound, "Contra Natura," in *Cantos*, 1965.

[47] Nuclear Regulatory Commission Special Inquiry Group,*Three Mile Island: A Report to the Commissioners and to the Public*, vol. I, 9.

The emergency feedwater pumps came on immediately to restore cooling to the steam generator, but since the block valves had been left closed, no water actually reached the generator. The heat accumulating in the primary cooling system caused water pressure inside the reactor to shoot up, and the PORV opened automatically to compensate. Sensors detected the still-rising pressure and instructed the reactor to scram. As noted before, however, the insertion of the control rods halts only the fission reaction, not the ongoing radioactive decay of the uranium oxide fuel. Ordinarily, the decay heat would be transferred to the secondary cooling system at the steam generator until the pressure dropped sufficiently for the PORV to re-close; but because the secondary feedwater was not circulating, the primary coolant water in the steam generator was essentially boiling away. The entire job of venting the excess heat and pressure fell to the PORV.

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[48] This was a "one-minute modification" of the kind that engineers now routinely warn against. "Clearing any system with instrument air as a pressure sources is a bad idea. Other pneumatic sources such as utility air, plant air or nitrogen should be used instead," writes British chemical-plant engineer R. E. Sanders. *The Management of Change in Chemical Plants: Lessons from Case Histories* (Oxford, U.K.: Butterworth-Heinemann, 1993) 80.

[49] A total feedwater shutdown, it is intereresting to note, could not have occurred in the Unit 1 reactor. There, half of the feedwater is always routed around the condensate polishers, and the polisher system is equipped with an automatic bypass valve rather than a manual valve like the one on the Unit 2 polisher. An operator's report noting these design discrepancies had so far been ignored. Jaffe, "Technical Aspects and Chronology of the Three Mile Island Accident," 40.

Even so, the PORV should have closed when the pressure finally dropped back to acceptable levels. It stuck open, just as it had done during tests the year before, allowing large volumes of vaporized coolant to rush out. (Analysts assessing the Babcock & Wilcox reactor design had calculated that the PORV would fail in this way only once in every 50 uses -- which were supposed to be infrequent anyway -- but the President's Commission later found evidence of at least 11 failures at other nuclear plants.[50]) Meanwhile, two high-pressure injection pumps started up automatically to flood the reactor core and prevent the fuel rods from being uncovered.

All of this happened in about 12 seconds, scarcely enough time for Zewe, Faust, and Frederick to make sense of the cascade of flashing lights and alarms in the control room. A number of conflicting signals confronted the operators, in combinations they had never seen in their simulations and drills. System pressure in the primary coolant loop was dropping, indicating that a possible loss-of-coolant accident was in progress. In fact, this was exactly what was happening, as the coolant water spewed out into the containment building through the stuck-open PORV; "the thing was simply uncorked," to use Perrow's colorful description.[51] But because the coolant was boiling, pockets of steam had formed throughout the primary system, forcing liquid water into the pressurizer vessel and creating water-level readings that falsely reassured the operators that the coolant level was still adequate. They even began to fear that the extra water entering through the high-pressure injection pumps would cause the pressurizer vessel to "go solid," a disastrous condition in which all control over the pressure level in the primary system is lost because the pressurizer, normally half-filled with steam, has entirely filled with water. Hoping to avoid this, Zewe ordered Frederick to shut down one of the high-pressure injection pumps and to cut the other to half power. Later, investigators would call Zewe's order the most significant error leading to the meltdown, but it was one the operators could hardly have avoided given the lack of time or consistent information about what was going on inside the reactor. The situation could now be described in the language of a simple high-school math problem: "The starting volume of the primary cooling system is 90,000 gallons. If coolant is leaking out at the rate of 320 gallons per minute but is being replaced at only 100 gallons per minute, how long will it take for the fuel rods to be completely uncovered?"

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[50] Perrow, 20.
[51] Perrow, 21.

The grim outcome of this exercise in related rates might have been avoided had Zewe and his subordinates been aware of the two valve problems. But the fact that the emergency feedwater block valves were closed went unnoticed until Ken Bryan, an operator from Unit 1, arrived on the scene some eight minutes into the accident. Workers were sent to open the valves, and emergency flow to the steam generator was restored. The stuck-open PORV remained that way, however, for another 2 hours and 12 minutes. Throughout this time the operators assumed that the valve was closed, since the indicator light which they believed would have been shining if the valve were open was, in fact, dark. This indicator, however, was of a particularly lazy design; it did not really indicate the position of the valve at all, but only whether an electrical current was flowing to the solenoid that was supposed to open and close the valve. So the fact that the light was off did not prove that the valve had actually shut, and another light that operators had installed to counteract this flaw had failed due to a faulty switch.

Zewe and his crew also dismissed another, more positive indication that coolant was leaking: a high temperature reading in the reactor coolant drain pipes leading to the containment building sump. The leaky PORV had often caused such high readings, Zewe testified later, but they were nothing to be alarmed about.[52] At about 4:40 a.m., a worker telephoned Frederick in the control room to notify him that more than six feet of water had accumulated in the containment sump. Fearing that the water might be radioactive (as it was) Frederick stopped the pumps that emptied the sump into an auxiliary building -- but not before some 8,000 gallons had already been deposited there and a small amount of radioactive vapor had been vented to the outdoor air. The operators failed to interpret the presence of the water in the auxiliary building as a sign that the PORV was stuck open; they imagined instead that a small pipe had broken somewhere. None of the information available to them had yet pierced their assumption that coolant levels were still high, a misperception compounded by the absence of instruments to monitor the reactor coolant level directly.

At about 5:13, the operators noticed that the four main reactor coolant pumps in the primary system were shaking violently. (The effect was uncannily similar to the climactic near-meltdown scene in *The China Syndrome*.) The vibrations were caused by "cavitation," or steam bubbles passing through the pumps, and were another sign that coolant level was dangerously low. To prevent the pumps from shaking themselves apart, the operators shut down two of them at 5:14, and the other two half an hour later. Still believing that the core was full of water, they hoped that natural convection currents would keep the fuel rods cool.[53] In fact, the coolant had now dropped to less than one-third of its usual level.

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[52] *The Need for Change: The Legacy of TMI* , 96.

Between 6:10 and 6:20, the coolant level bottomed out. The 12-foot fuel rods were now more than half uncovered, and although the operators and other personnel summoned to the plant had finally diagnosed and closed the stuck PORV, it was too late. The core had begun to melt. Events from this point forward were reconstructed only years later, after the cleanup and defueling process was complete, but it appears that the zirconium alloy cladding covering the uranium pellets first ruptured, then burned. A molten mixture of zirconium and uranium oxides flowed down toward the center of the reactor, forming a six-inch crust on top of the remaining water. By 7:00 a.m., operators had begun to send more cold water into the core, but this only had the effect of shattering the fractured, overheated fuel assemblies and creating a large void at the reactor's center. Molten fuel and cladding accumulated on top of the crust until 7:46, when the crust broke and the fuel burned through the reactor's inner wall. In less than a minute twenty tons of the molten mass migrated to the bottom of the reactor shell, where water cooled it enough to prevent it from burning through the reactor vessel and dropping onto the floor of the containment building itself.[54] A later analysis showed that had the PORV remained open for another thirty minutes with the injection pumps still at low power, a full meltdown and reactor vessel breach would likely have resulted.[55]

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[53] *Three Mile Island: A Report to the Commissioners and to the Public,* 18;*The Need for Change: The Legacy of TMI* , 99.

[54] Booth, "Postmortem on Three Mile Island," 1343-1344.

[55] Perrow, 29.

"All Hell Broke Loose"

Before most people in the TMI region had even left their homes for work or school that Wednesday morning, then, the most dangerous phase of the accident was over. But no one knew this at the time, and TMI's operators were only beginning to realize what had actually occurred inside the reactor. The public-safety crisis would not reach its peak until Friday, when thousands evacuated the area, heeding experts' warnings that a potentially explosive hydrogen bubble might be building up inside the reactor vessel. At this point in the story, however, it will help to step back from the technical details in order to assess the depth and seriousness of the impressions the accident conveyed to the residents of the Middletown-Harrisburg area and to the larger TV-viewing public.

The best one-word summary for those impressions is *confusion* -- confusion evident among TMI's operators and owners, among experts inside and outside the NRC, and among state and federal officials responsible for the public safety. It became terrifyingly obvious to the lay public that the people supposedly in charge of the nuclear machinery were themselves at wits' end over the accident. Given that Vietnam, Watergate, and Love Canal, among other episodes, had already conditioned Americans to be unsurprised by high levels of official bad faith and incompetence, the logical conclusion for many observers was not that different officials should be put in charge but that LWR technology was too dangerous to entrust to anyone, let alone to profit-minded utilities and promotion-minded regulators. Whatever faith the public still placed in the U.S. nuclear power industry before the accident, much of it evaporated along with Unit 2's vital coolant.

The immediate response to the accident outside the TMI plant gates might be described as a study in "information pathology." With the possible exception of General Public Utilities, no single person or group behaved irresponsibly, attempted to conceal known hazards, or knowingly disseminated misleading information. Reporters acted as effectively as they could under difficult circumstances, spreading the facts as they were known with a minimum of error and sensationalism; NRC officials, once they had taken over public-information duties at the accident site, were cooperative and forthright; and Pennsylvania emergency management officials acted cautiously and according to the best information available to them. Yet the net result was chaos, fear, and panic on a scale to match the bafflement of the technicians inside the plant. The breakdown of public trust in authority structures -- the hierarchy of sources to which the public usually looked for advice on health and safety matters -- stemmed from rampant contradictions in these authorities' words and actions. Utility and government officials repeatedly claimed, on the one hand, that the danger was minimal and that events inside the plant were "under control." But conflicting claims about exactly what these events were betrayed the officials' true confusion and ignorance. This was an understandable condition for them to be in, given the sheer complexity of the plant and of the accident's progress,[56] but by not admitting their ignorance sooner officials only invited a worse breakdown of trust later. The "information pathology," therefore, had its origins in the technology itself, and was only exacerbated by officials pretending to know more than they did. Given the morass of conflicting signals available to the the population around Three Mile Island, evacuation was a sensible alternative.

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[56] Indeed, accounts of the accident like the preceding one could only be pieced together after weeks, months, or years of investigation.

The substitution of blithe reassurances for unvarnished facts about the TMI plant was a pattern established long before the accident. Metropolitan Edison, the GPU subsidiary that ran Three Mile Island, employed four public information officials whose main function was to disseminate weekly press releases written by plant engineers. The releases tallied startups (as opposed to shutdowns), used misleading jargon such as "deenergized power distribution bus" (i.e., a blown fuse), and unfailingly described technical problems as inconsequential to public health and safety. Unfortunately, local reporters failed to perceive the pattern of safety problems the press releases cumulatively indicated.[57] From 1976 to 1978 the eight newspapers in the region published, between them, an average of about two articles each week on the Three Mile Island plant, but most of these focused on Unit 2 licensing hearings and milestones in the construction and startup process rather than on safety and operating setbacks.[58]

Despite the dearth of critical public attention to events at the plant, a local anti-nuclear group, Three Mile Island Alert (TMIA), had come into existence as early as 1977.[59] Another, older group, the Environmental Coalition on Nuclear Power, tied together some 35 citizens' organizations opposing plant licensing in Pennsylvania and New Jersey. These early activist organizations, however, boasted little direct support from the people of the region. Local residents were not exempt from the national trend of growing opposition to nuclear power. But the vast majority, if they questioned TMI's presence at all, were only sympathizers of the anti-nuclear movement, not committed activists. As one resident said later, "The events at Seabrook in 1977-78 did arouse my consciousness...but I'm ashamed to admit that I kept TMI and other power plants out of my mind."[60] The years were not long gone when syndicated columnist Mary McGrory had called southeastern Pennsylvania "the confidence-in-authority capital of the country."[61] Only the alarming reports that began to emanate from Three Mile Island on the morning of March 28 would push residents solidly into the anti-nuclear camp.

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[57] Friedman, "Blueprint for Breakdown," 118-119.

[58] U.S. President's Commission on the Accident at Three Mile Island, *Report of the Public's Right to Information Task Force* (Washington, D.C.: Government Printing Office, Oct. 1979) 43.

[59] Walsh, 49-51.

A traffic reporter who had been monitoring police radio communications broadcast the first news of the accident on Harrisburg station WKBO at 8:25 a.m. The Associated Press reported soon after that Metropolitan Edison had declared a "general emergency" at the site, but "neither the utility, nor the NRC, nor the state explained clearly what a general emergency was," noted a report by the President's Commission assembled to investigate the accident. People calling GPU's headquarters in Reading that morning were told, quite falsely, that there had been "no recordings of any significant levels of radiation" either inside or outside the plant and that there was "no danger of meltdown." At an 11:00 a.m. press conference, Lieutenant Governor William Scranton, the head of the Pennsylvania Emergency Management Agency (PEMA), announced that some radiation had been vented into the atmosphere, but he did not say how much.

A statement released by GPU at about the same time announced that there had been a "malfunction" at TMI-2 in which "some damage to the fuel cladding may have occurred" and that the company was "presently monitoring some low level release of radioactive gas beyond the site boundary." At the plant itself, however, the public information staff maintained that "No [off-site radioactive releases] have been found, and we do not expect any." In fact, field scientists for the Pennsylvania Department of Environmental Resources had detected airborne radiation of up to 10 millirems per hour -- more than ten times the normal background level, but not enough to require an evacuation.[62] At 4:30 p.m., Scranton told reporters that "Metropolitan Edison has given you and us conflicting information...There has been a release of radioactivity into the environment." Scranton said state officials were concerned most about the accumulation of radioative iodine in the thyroid glands of those exposed to the radiation.[63]

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[60] Walsh, 83.
[61] Quoted in Walsh, 64.

At about 1:50 Wednesday afternoon, meanwhile, operators inside the TMI-2 control room heard a heavy thud. The station manager, Gary Miller, who was leaving for a briefing with Scranton, dismissed the thud as the noise of a closing ventilator. Though computers registered indications of a "pressure spike" of 28 pounds per square inch inside the containment building, but operators "wrote it off...[as] possibly instrument malfunction."[64] In fact, there had just been an explosion of hydrogen gas released from the reactor. Zirconium in the overheated fuel cladding had interacted with water in the primary coolant system, bonding with its oxygen and freeing hydrogen, which then bubbled out into the containment area where it was ignited, probably by a spark from an electric pump. The overpressure produced by the explosion was fully half the maximum for which the building had been designed. If the utility had not acceded to the state's earlier demands that the containment be reinforced to withstand the impact of a jet airliner (in deference to the nearby Harrisburg airport), the building might well have been too weak to contain anything after the hydrogen burn.[65]

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[62] The average dose from natural background radiation in the United States is 100 millirems per year; NRC regulations permit nuclear plant workers to receive up to 3 rems every 3 months.

[63] *Report of the Public's Right to Information Task Force* , 79, 83, 85, 100.

[64] *The Need for Change: The Legacy of TMI* , 107.

By the next day, the situation seemed to have stabilized. Because no one recognized that a hydrogen explosion had occurred, it went unreported. Residents paid close attention to the ongoing media coverage and were skeptical about the reports of low radiation, but few yet saw any compelling reason to leave the area. In testimony before Congress that Thursday, NRC chairman Joseph Hendrie asserted that there was "no serious ongoing problem" at Three Mile Island.[66] That afternoon, however, Met Ed angered many, including Pennsylvania Governor Richard Thornburgh, by dumping some 400,000 gallons of radioactive xenon-contaminated wastewater into the Susquehanna River without notifying anyone outside the plant. Thornburgh later said the utility was "insensitive to our responsibility to inform the public and to take appropriate action." An enraged press corps learned of the dumping only the next morning. "Why weren't we told about this for ten hours?" one reporter asked. Destroying in a single sentence whatever was left of the utility's credibility, a Met Ed vice president replied, "I don't know why we need to tell you each and every thing that we do."[67]

The only accurate description for the events of Friday, March 30, was the one many local residents would later use: "All hell broke loose."[68] No one yet knew whether the reactor core temperature was under control. At 7:10 a.m., in an attempt to reduce pressure in the the coolant water supply tank, an operator ordered the transfer of radioactive gases from that tank to another, the waste gas decay tank. Some of the gas escaped through leaky pipes in the auxiliary building and was vented into the atmosphere. Helicopters hovering above the plant reported radiation readings of up to 1,200 millirems per hour. In what John Kemeny, head of the President's Commission, would later call a "horrible coincidence," an official participating in a briefing at NRC headquarters in Washington had just shared an off-the-cuff calculation that if the waste gas decay tank relief valve were to be opened, some 1,200 millirems per hour would be released on the ground, a level exceeding EPA exposure guidelines for "sensitive individuals." When the news of helicopter readings of exactly this amount reached the NRC, the result was "significant apprehension," according to one official. Unaware that the waste gas decay tank was not actually being vented and that the radiation measurement had been taken from the air directly above the plant, not from off-site, the agency recommended to PEMA that the state begin an evacuation of everyone within five miles of the plant. Before Governor Thornburgh could approve such an order, however, PEMA had alerted other agencies and radio stations that evacuation was imminent, and the exodus was underway. Officials at the plant learned of the evacuation warning only when one of them drove into Middletown to pick up some sandwiches and saw that shoppers were "scurrying away as though being pursued." "What are you people doing to us?" station manager Miller angrily asked one NRC inspector.

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[65] Perrow, 29-30, 41.
[66] Walsh, 35.
[67] *Report of the Public's Right to Information Task Force,* 124-125.
[68] See, for example, Walsh, 39; *The Need for Change: The Legacy of TMI,* 123.

Within an hour the confused radiation reports were ironed out and Thornburgh countermanded the evacuation notice, instead advising people within five miles downwind of the plant to stay indoors with their windows closed. But the NRC's own report later acknowledged that the premature evacuation warning had let loose "fear that [rolled] around the area like a loose cannon, doing incalculable damage to the morale of this placid, stable region."[69] When Thornburgh announced at 12:30 p.m. that pregnant women and young children should leave the entire five-mile zone, most residents took this to mean there was a serious emergency. Parents removed their children from school, customers jammed banks and grocery stores, phone lines overloaded, and highways and bridges clogged. Over the next three days, more than 200,000 people -- some 60 percent of residents within the five-mile radius, 40 percent within fifteen miles, and 11 percent within twenty-five miles -- would flee their homes.[70] In the absence of trustworthy information from Met Ed or the NRC, the evacuees' overwhelming impulse was "better safe than sorry." One later recounted, "Either they were lying to us about the radiation releases or else they didn't really know what was coming out of that damn plant -- either way, I didn't want to stay around."[71]

While the evacuation was going on around them Friday and Saturday, operators and officials inside the control room were preoccupied with a new problem. A 1,000-cubic-foot hydrogen bubble had been detected inside the reactor core, a product of the same zirconium-water reaction that had led to Wednesday's explosion in the containment building. A hydrogen explosion inside the core might rupture the reactor vessel, spilling highly radioactive materials onto the containment floor or even causing a full meltdown. The hydrogen could not explode, however, unless there were also free oxygen inside the reactor, and some NRC scientists calculated that over several days, a process known as radiolysis -- the breakdown of coolant water into hydrogen and oxygen by radioactive bombardment from the decaying fuel --

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[69] *Three Mile Island: A Report to the Commissioners and to the Public*, 59-67; *Report of the Public's Right to Information Task Force*, 125-142; *The Need for Change: The Legacy of TMI* , 116-119.
[70] Walsh, 37.
[71] Walsh, 41.

could liberate enough oxygen to make the hydrogen flammable. Saturday evening, the Associated Press reported estimates from NRC sources that the bubble might become explosive within two days. But engineers at Babcock & Wilcox insisted that the excess hydrogen would suppress radiolysis altogether. In a late-night press conference on Friday, NRC spokesman Harold Denton denied there was any danger of an explosion, but disagreement over the question persisted among experts throughout the weekend, even as President Jimmy Carter and First Lady Rosalynn Carter toured the plant on Sunday. Press reports highlighted the conflict. As the NRC's accident report later observed, "The hydrogen bubble never explode[d] in the reactor vessel; it [blew] up instead in the media."[72] In any event, the bubble controversy had a chilled public perceptions of the nuclear establishment. "People saw the disorganization of the system. They saw technical experts not knowing what was going on, and I think that made people very uncomfortable," observes nuclear engineer Margarita Crocker, an expert on nuclear regulation in the U.S., Germany, France, and Japan.[73]

The bubble trouble soon passed. Beginning Sunday evening, operators were able to draw off most of the excess hydrogen using the reactor's degasification system. On Tuesday, Denton announced that the bubble had been eliminated. (He did not add that the NRC's original calculations about the generation of oxygen had been in error, creating needless panic.) Residents soon began returning from their places of escape -- some as far away as Missouri -- and on April 9 Governor Thornburgh announced that pregnant women and children could safely re-enter the area. By April 27, the Unit 2 reactor had been put in "cold shutdown," with natural convection currents absorbing the remaining decay heat.[74] The total amount of radiation released during the accident, according to later estimates, was so small that it would lead to less than one extra cancer death in the TMI region over the coming decades.[75] The immediate danger had passed. But the citizen response to the crisis was just beginning.

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[72] *Three Mile Island: A Report to the Commissioners and to the Public*, 80.
[73] Telephone interview with Crocker from her home in Somerville, Massachusetts, Jan. 14, 1993.

Shifting Ground

The accident heightened the already-strident national debate between pro-nuclear and anti-nuclear contingents. Both launched public-relations campaigns to capitalize on renewed media attention to the issue. Opponents framed the accident as the realization of all their worst predictions about the hazards of LWRs. The nuclear industry, pointing out that the reactor vessel was never breached and only a tiny amount of radiation escaped, portrayed it as a successful test of the defense-in-depth strategy. Taking aim at the anti-nuclear camp, industry pundits reached into their quiver of epithets and came up with such phrases as "calamity howlers," "purveyors of panic," "Doomsday Lobby," "quasi-religious crusade" and "a fierce Lilliputian minority...strapping down the nation's energy supply like Gulliver."[76] The Union of Concerned Scientists, in turn, bought a full-page advertisement in the *New York Times* calling the nuclear enterprise "a technological Vietnam...run by people too obstinate to disengage us despite all the evidence in the world that the nuclear power dream has become a nightmare." The ad admonished citizens that "only *your immediate action* can stop the incompetence, malfeasance, industry arrogance and government insensitivity that is hurling us all towards the next nuclear accident."[77] Escalating the war of words was a two-page notice in the *Wall Street Journal* written by physicist Edward Teller and clandestinely funded by Dresser Industries (the manufacturer of the faulty pressurizer relief valve at TMI). Teller's ad claimed, incredibly enough, "I Was the Only Victim of Three Mile Island." Teller had suffered a heart attack while lecturing in defense of nuclear power, and now he wrote that "I feel compelled to use whatever time and strength are left to me to speak out on the energy problem...Unless the political trend toward energy development in this country [i.e., away from nuclear power] changes rapidly, there may not be a United States in the twenty-first century."[78]

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[74] *Three Mile Island: A Report to the Commissioners and to the Public*, 87.

[75] It is estimated that a total of 2 million Curies of radioactive noble gases and 17 Ci of iodine radioisotopes were released as a result of the accident. Achilles G. Adamantiades et al., *A Guide to Nuclear Power Technology: A Resource for Decision Making* (New York: John Wiley & Sons, 1984) 737. This was a very small release compared to the 200 million Curies of radioisotopes estimated by Alexander R. Sich to have been released during the Chernobyl disaster; see Chapter 5.

[76] James J. Kilpatrick, "Yes, it was a disaster," and Patrick J. Buchanan, "Now, the anti-nuclear cry," *Washington Star* (April 7, 1979); Charles Bartlett, "Let the public decide," *Washington Star* (April 4, 1979).

In Washington, Three Mile Island made nuclear power a political issue in a way it had never been before. Under pressure from anti-nuclear Democrats like California Governor Jerry Brown, Senators Edward Kennedy of Massachusetts and Gary Hart of Colorado, and Arizona Representative Morris Udall -- all Presidential hopefuls -- President Carter moderated his outspoken support for the nuclear industry. Carter said shutting down existing nuclear plants was "out of the question," but he suggested that the U.S. should move to develop alternative energy sources and reduce its reliance on nuclear power.[79] Even before the Unit 2 reactor had cooled, the usual round of official investigations were underway, with various bodies --

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[77] *The New York Times* (April 8, 1979) 22.
[78] *The Wall Street Journal* (July 31, 1979) 24-25.
[79] Lyons, "Antinuclear Politicking Makes Odd Bedfellows," 2E.

Congress, the executive branch, the NRC -- vying to be the first to assign blame for the accident.

The role of the official accident investigation commissions that often form in response to severe failures has always been a dual one: To root out the accident's causes in hopes of preventing similar problems in the future, but also to restore public confidence in the technology in question by demonstrating that the causes of failure are thoroughly understood and, by implication, controllable. The two major post-mortems on Three Mile Island presented clear and comprehensible accounts of the accident and ended by distributing blame fairly evenly across the involved parties -- GPU, Babcock & Wilcox, PEMA, the NRC, and the plant operators. But no one who read these reports closely could have come away reassured that combinations of events like those that led to the meltdown were even *in principle* preventable. So many things went wrong during the accident -- as the commission reports and, later, Perrow' *Normal Accidents* made graphically clear -- that to offer guarantees against a similar accident in the future would have been ludicrous. Indeed, while the reports called for numerous technical and organizational changes to improve reactor safety (not least within NRC itself) they also cautioned ominously that good evacuation plans for the populations around nuclear plants were the best final defense against the danger of a meltdown.

The months after the TMI accident, as the facts of the accident began to come to light, were heady ones for critics of nuclear energy: for the first time, what Robert Kates had called that "exceedingly rare event," the renunciation of a technology, seemed plausible. An accident as serious and well-publicized as the one at Three Mile Island could not help but lead to sober public discussion of the nuclear power's pros and cons. In a message to the utility industry, NRC Commissioner Richard Kennedy conceded that "the inherent desirability or undesirability of nuclear power" was now at issue and said that "its ultimate evolution must depend on the political process rather than the regulatory process."[80] Another commissioner, Victor Gilinsky, mused that Three Mile Island could "represent for the nuclear reactor what the Hindenburg was for the airship."[81] Daniel S. Greenberg, journalist and later publisher of the influential *Science & Government Report*, wrote in the *Washington Post* that "Despite what [the nuclear apologists] say, the fact is that, given the political will, public cooperation and shrewd exploitation of non-nuclear energy sources, we could get by without nuclear power for the next couple of decades...The disaster that we're all now brooding over provides an opportunity -- though one of short duration -- to rethink and perhaps re-legislate the role of nuclear energy in American life."[82]

Throughout the first year after the accident, the force it added to anti-nuclear arguments seemed strong enough to assure a substantial victory for nuclear opponents in the Three Mile Island region: the permanent shutdown of the plant, including the undamaged Unit 1 reactor. Approximately 600,000 people lived within 25 miles of TMI, and whether they had stayed or fled during the accident, most emerged from the experience angry and afraid. Though many residents of this predominantly agricultural area had paid little attention to the plant before the accident, they now viewed it as a technological monster in their midst. "There is a good possibility that the emotions of the people here are so strong," one NRC official said in March, 1980, that "one could well speculate" that the plant might never reopen.[83] Many felt that GPU had, in essence, broken the "social contract" by which concern for public health and safety was to be put ahead of profit, and that the authorities who were supposed to have enforced this contract -- mainly, the NRC -- had shown themselves to be little more than co-conspirators in the utility's bad faith.[84] Coming together first in everyday conversation with their neighbors, and later in organized anti-TMI groups throughout the region, residents appear to have formulated three main arguments in favor of a permanent shutdown: first, that the safe exploitation of nuclear power was beyond society's technological and organizational capabilities; second, that the parties who had violated the "social contract" in the first place could not be trusted to honor it in the future; and third, that the very least residents deserved as compensation for the trauma imposed by the accident was to be free of any renewed threat.

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[80] Richard T. Kennedy, "Remarks Before the Edison Electric Institute Spring Legislative Conference, Washington, D.C., June 12, 1979," (United States Nuclear Regulatory Comission release no. S-8-79).

[81] Victor Gilinsky, "Remarks Before the Government Affairs Committee of the American Newspaper Publishers Association, Washington, D.C., Sep. 19, 1979," (United States Nuclear Regulatory Commission release no. S-11-79).

[82] Daniel S. Greenberg, "Nuclear Power: Reform Not Abolition," *The Washington Post* (April 3, 1979).

The first argument was fueled by abundant media coverage of the accident and the investigations. For anyone who watched television or read a newspaper during the crisis, the accident amounted to a crash course in LWR technology. "Never before TMI had the American people been presented, in such comprehensive fashion, with information on how nuclear reactors operate," observed the NRC's Kennedy.[85] The nature of heat generation inside the core, the transfer of energy from the primary to the secondary feedwater loop, the spaghetti-like plumbing of the emergency core cooling systems, the bewildering sameness of the dials and switches in the control room -- all this and more were part of the media's presentation. For TMI-area residents the information was doubly relevant, and the effects of this instant education profound. The accident greatly heightened residents' awareness of, and antipathy toward, the TMI facility and the nuclear establishment in general, as press accounts and strong quantitative and anecdotal social-research data attest.[86]

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[83] Ben A. Franklin, "Public Anger May Doom Crippled Nuclear Reactor," *The New York Times* (March 21, 1980) A14.

[84] For an extended discussion of the "social contract" metaphor as it applies to Three Mile Island, see Goldsteen and Schorr, 175-190.

[85] Richard Kennedy, *Remarks* (June 12, 1979).

Many residents concluded after the accident that nuclear energy was simply too complex a technology for humans to manage safely.[87] "It's a new field. They really don't know all the things they should know about it," one 25-year-old woman said. "There are so many things that could go wrong down there, I'm sure something will get screwed up," said a successful businessman. One weatherworn farmer allowed, "Maybe the accident could have been blamed on the operators too instead of the plant itself. I believe the operators were at fault, I believe it. You got to know what you are doing." A young man with two small children observed that "The utility companies, in the need for a type of energy that they can sell to people, that they can control, have gone ahead with nuclear power regardless of the fact that there is nothing to do with the nuclear waste...I do not see it as a good source of power...But if it is absolutely necessary, then they should put it in nonpopulated areas." And this opinion, worth quoting at length, came from a woman who gave birth to a son about a month after the accident:

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[86] See especially Goldsteen and Schorr, 117-153; Sandra Prince-Embury, et al., "Perception of Control and Faith in Experts Among Residents in the Vicinity of Three Mile Island," *Journal of Applied Social Psychology* (Vol 17., no. 11, 1987) 953-968; Brad Richardson, et al., "Explaining the Social and Psychological Impacts of a Nuclear Power Plant Accident," *Journal of Applied Social Psychology* (Vol. 17, no. 1, 1987) 16-36; John Sorenson, et al., *Impacts of Hazardous Technology: The Psycho-Social Effects of Restarting TMI-1* (Albany: State University of New York Press, 1987); P. Walker, et al., eds., *Proceedings of the Workshop on Psychological Stress Associated with the Proposed Restart of Three Mile Island, Unit 1,* (United States Nuclear Regulatory Comission, April 1982);

[87] All the quotations in this paragraph are from interviews conducted by Goldsteen and Schorr; see their *Demanding Democracy After Three Mile Island*, pages 51-111.

> I feel very angry about it, really, because I just feel that there was so much incompetence on the part of the utility, on the part of the NRC, on the part of the local governments...It seems to me that it's a technology in general that's really gotten away from us. When the accident happened, there was so much floundering around that, at the time, I was thinking it was just a cover-up. They don't want to admit that they goofed...There are so many alternatives we could explore, you know, that I don't really think we have to go the nuclear route...But it's pretty obvious that the nuclear industry -- they have so much money tied up in it now, and all the plants are extremely expensive to build, and they aren't going to get their money back off of them, you know. It's like, they made a mistake twenty-five, thirty years ago when they opted to go nuclear, and now instead of saying, "Hey, we goofed, This is not the way we should have gone," and [they] just let them sit where they are...I understand they can't just shut them all off tomorrow because a lot of areas of the country really depend on nuclear for electricity...It just seems like such a pigheaded course to me. I just can't see why they don't admit their mistake. They seem to feel that they're above the law. They're above their responsibilities to the ratepayers and the public in general...I never was particularly pronuclear. I always felt that it was not a very safe thing to fool around with, that we really weren't ready for it...It seemed that as far as industry and government was concerned, they took it all very lightly and pooh-poohed the idea, [saying] that anyone who was against [nuclear power] was an alarmist and going around crying doom, you know...I guess [the accident] just sort of crystallized my feelings. I feel more strongly since it happened....I think they were taking it so much for granted. They had all these technological goodies, and it was just going to keep this safe, and the backup systems were going to work. So don't worry about it. Just push the buttons. That's it. But it just doesn't seem to be working that way. I really feel that sooner or later, maybe not necessarily at TMI, but someplace in the world, there's really going to be a bad, bad accident...Life obviously is not a fairy tale, never has been and never will be, but after this, it just really made me wonder, "Are we going to be able to overcome this? Is our technology going to do us in before we wake up and look at it?"

Such sentiments, though not as coherently expressed by others, were not unusual. Surveys conducted in the years 1979-1986 showed that between 60 and 72 percent of TMI area residents considered living near any nuclear power plant to be dangerous and that 81 to 83 percent considered Three Mile Island in particular to be either "dangerous" or "very dangerous." Between 39 to 46 percent said they would have moved farther away from TMI if they could have afforded to do so. Between 57 and 79 percent said they did not trust the utility or the federal government to regulate nuclear power adequately, and 36 to 41 percent said they favored a total ban on nuclear power.[88]

Social scientists found that residents' *first-hand experiences during the accident and evacuation,* rather than any views or political positions they held beforehand, were the most important factor explaining their post-accident attitudes toward nuclear power. One group of social psychologists who conducted a multivariate path analysis on survey data taken after the TMI accident concluded that "a bad experience with a threat seems to alter how people subsequently distribute their supply of 'worry beads'...Impacts on people seem to be caused by individual and group experience with the accident much more than prevailing pre-accident population characteristics."[89] In other words, it was what people learned during the accident -- that the threat of meltdown was real, that reactor systems were complex and difficult to manage, and that TMI's operators and regulators were apparently not up to the task -- that created their unfavorable attitudes toward LWR technology.

The collapse of old patterns of trust in authority in the communities around Three Mile Island was equally thorough. As we have seen above, and as sociologists confirmed, "Faith in experts crumbled in the wake of the accident as conflicting statements were made by industry, government officials and through news media."[90] Earlier technological disasters had led to similar collapses (the 1972 Buffalo Creek flood, as described by Kai Erikson and others, was the archetype in the disaster literature[91]) but at TMI the state of relations between citizens and leaders was especially critical. The prospects for a mutually satisfactory resolution of the Unit 1 restart controversy would obviously be minimal if citizens, utility officials, and regulators could not negotiate from a base of mutual respect. In a 1980 survey, fewer than 8 percent of the population within 25 miles of TMI felt that Met Ed was either believable or reliable, and the NRC fared little better.[92] Said one resident, "We resent the NRC even more than Met Ed because the feds were supposed to be in control and they didn't know what was going on around here."[93]

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[88] Goldsteen and Schorr, 118-119, 121, 152-153, 171.

[89] Richardson et al., "Explaining the Social and Psychological Impacts of a Nuclear Power Plant Accident," 26-27, 30.

[90] R. Holt, quoted in Prince-Embury, "Perception of Control and Faith," 955.

[91] Kai T. Erikson, *Everything In Its Path:The Destruction of Community in the Buffalo Creek Flood* (New York: Simon & Schuster, 1976).

At the heart of this ill will was Pennsylvanians' belief that the nuclear establishment, in its obsession with "exploiting the peaceful atom," had deliberately compromised their safety and would do so again if given the chance. They were also convinced that the institutions of nuclear power were beyond democratic control. "Money has spoken, and we the people do not matter at all. We can be replaced," said one cynical resident. "Met Ed is concerned about their money, and I think that's where the key lies," said another. "They want to get that thing back in operation, and that seems to be all they're concerned about."[94]

From the moment GPU announced plans to bring Unit 1 back on-line, area citizens were overwhelmingly opposed to the idea. Surveys taken during the six-year restart controversy showed opposition to be steady at about 70 percent.[95] At first the accident created an energetic local movement for "strong democracy" -- direct citizen participation in the restart decision through hearings and referenda.[96] But as the case moved into the courts and it became clear that the restart could not be prevented solely through local political action, the movement's efforts grew narrower and more specialized. While safety concerns were at the core of citizen opposition, the court battle over the restart would come to hinge on a number of unrelated questions: whether, for example, the resumption of operations at Unit 1 would significantly impair residents' social and psychological well-being. Many residents said the accident had been an extremely stressful experience and predicted that a Unit 1 restart would add to their feelings of fear, anxiety, paranoia, hopelesness, and powerlessness, perhaps also contributing to medical problems, family strife, neighborhood conflict, and community decline.[97] TMI opponents were forced to stress these psychosocial effects in their legal efforts because regulators discounted their concrete health and safety concerns; in essence, the strategy called on the NRC to include citizens' mental health as a component of Unit 1's "environment," the "impact" upon which should be duly "assessed" before TMI's operating license could be re-issued. The psychologization strategy was activists' final attempt to beat the regulators at their own game -- a risky proposition in any industry, let alone one as closed and defensive as commercial nuclear power. Given the legislative and regulatory history of nuclear power in the United States, the eventual Supreme Court decision allowing GPU to restart the Unit 1 reactor was all but inevitable. What is noteworthy is that it was six years in coming.

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[92] Appendix A, Table A-8, in John Sorenson, et al., *Impacts of Hazardous Technology*, 116, 179.

[93] Walsh, 41.

[94] Goldsteen and Schorr, 170, 172.

[95] Ibid., 156.

[96] Many analysts, including Langdon Winner and Peter Stillman, have argued that nuclear power plants are inherently resistant to democratic control, but at the same time too complex

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for experts and organizations to manage reliably. Stillman writes: "Energy production by nuclear power is inimical to democracy and prerequisites of democracy such as equality, an open society, and the free flow of information...[yet] the manifold problems at TMI raise questions about the competence and legitimacy of technical experts and government agencies." In such a case, intervention to shut down the technology through "strong democracy" may be the only sensible course. Stillman, "Three Mile Island: A Case of Disinformation," *Democracy* (Fall, 1982) 66-78.

[97] Sorensen et al., 40.

"Moment of Truth"

In the reshuffling of local loyalties after the accident, Three Mile Island Alert (TMIA) was one of the few organizations to come out ahead. The small anti-nuclear group, operating out of a basement apartment in Harrisburg, had been warning area residents about deficiencies at the plant since 1977. Overnight, the accident gave the group new credibility among residents who had formerly considered the anti-nuclear movement a part of the "radical fringe." (It didn't hurt that the group's telephone number was listed right after the Three Mile Island plant itself; many callers trying to reach utility spokespersons wound up speaking with TMI opponents instead.[98]) Thousands of people who had never acted on their convictions about nuclear power were now roused to join TMIA and the four other major anti-restart groups that quickly sprung up in the region: the Susquehanna Valley Alliance, the Newberry Township Steering Committee, People Against Nuclear Energy (PANE), and the Antinuclear Group Representing York (ANGRY). Sympathizers were becoming activists. When some 150,000 people gathered at a Washington, D.C. anti-nuclear rally on May 6, 1979, several hundred TMI residents were there as honorary leaders.

Preventing the Unit 1 restart was their overriding concern, but area activists took broad aim at the nuclear industry, as names like PANE and ANGRY implied. The Susquehanna Valley Alliance declared its long-term goal to be the phasing out of nuclear power stations in the U.S.[99] A ten-page statement released by the faculty of the nearby Lancaster Theological Seminary near Three Mile Island read like both a prayer and a call to arms:

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[98] Walsh, 49.
[99] Walsh, 81.

> We confess our responsibility for conditions leading to the Three Mile Island accident. We confess we have become increasingly aware of the danger of nuclear power, but we did not publicly advocate stopping the construction of nuclear facilities...We believe that although nuclear energy is part of God's good creation, it has been developed in ways which have become destructive in our time. The accident at Three Mile Island highlights these harmful aspects of nuclear power in a dramatic way that summons the Church to speak out...Evidence now strongly indicates that nuclear power in its present form is unsafe, uneconomical, and unsound ecologically...At times in history, an occurrence takes place which breaks the seemingly inevitable sequence of events and opens up new possibilities for creative participation...Selma, Kent State, and Watergate were occasions of this kind. Three Mile Island is also such an event, a moment of truth in which the grip of the 'powers' over us is at least temporarily broken. In such a moment our values are judged and we are given a suddenly-expanded opportunity to decide the course of our future...In response to Three Mile Island we summon the Church to pray, to think, to act.[100]

The seminarians called for a moratorium on the construction of new nuclear plants and the rapid phaseout of existing plants. Other groups lobbied for the repeal of the Price-Anderson Act ensuring utilities' invulnerability to liability for reactor accidents. Though the regional anti-nuclear movement had no single agenda or unified leadership, it was clearly awake to the national, even global implications of the events at Three Mile Island.

Activists quickly recognized, however, that the trans-local character of the nuclear establishment itself would be the biggest barrier to grassroots change at TMI. Regulators and utility officials voiced a commitment to "public involvement" in decisions about plant siting and operation, but they clearly believed that the experts employed by large technical organizations should have the final say. (As we heard an official of the American Electric Power Service Corporation assert in Chapter 1, "a specialized technical activity such as power system planning cannot be carried out in an open forum or in the atmosphere of a town hall."[101]) Early on, the NRC's Atomic Safety Licensing Board (ASLB) agreed to hold public hearings on GPU's proposal to restart

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[100] Quoted in Walsh, 81-82.

[101] Theodore J. Nagel, "Operating a Major Electric Utility Today," *Science* (Sep. 15, 1978) 985-93.

Unit 1, but few area residents believed that the heavily pro-nuclear body would reject the proposal. One fifty-year old woman living in Newberry Township told interviewers "we should have a say" in the reopening of TMI "because we're the victims." She added, however, that "We'll spout off a little bit, or maybe we'll go to the capitol building and have banners, you know...but in the end the little guy just [has] no say. I've never seen the little guy win yet when you come up against a big organization."[102]

Though convinced that the hearings' outcome would go against them, the six area groups participated anyway, using the opportunity to build a legal record in preparation for later court challenges. The hearings went on until July, 1981. Activists expected the NRC to rule hastily in favor of the Unit 1 restart once the hearings were over, but now the trouble-prone plant was hit by two new problems. NRC investigators uncovered evidence that GPU operators had cheated on examinations, and the utility discovered that thousands of steam tubes in Unit 1's secondary cooling system were defective, necessitating lengthy delays for repairs. Activists capitalized on these setbacks. They collected enough signatures to put a nonbinding restart referendum on the May, 1982, ballot in three of the four counties surrounding TMI. Voting was 2-1 against restart.

Meanwhile, PANE and the other groups sued the NRC, contending that the National Environmental Policy Act still required the agency to include psychosocial effects in its consideration of environmental impacts during the relicensing procedure. In January, 1982, the U.S. Court of Appeals for the District of Columbia ruled in PANE's favor, and the NRC commissioned a group of geographers, anthropologists, sociologists, and political scientists to study the proposed restart's implications.[103] At the same time, however, the agency appealed the ruling. The Supreme Court later overturned the appeals court, finding that the NRC was not required to take the fact of the Unit 2 accident into account in its decision about Unit 1, and that Congress had not had psychological harms in mind when it wrote the Environmental Protection Act. In July, 1982, the ASLB recommended that Unit 1 be allowed to restart, and the NRC commissioners set December 10 as the date for their own final vote on the issue.

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[102] Goldsteen and Schorr, 75-76.

The "final hearing" before the restart vote, held November 9 in a high school auditorium in Harrisburg, marked the first time all five NRC commissioners had appeared together in a public forum and was a moment of high tension. Edward J. Walsh, a Pennsylvania State University sociologist who attended the event as an observer, reported that "although the original program called for only thirty citizen representatives to speak to the commissioners, more than forty-five took the microphones as the five NRC officials sat semi-captive to the overwhelmingly hostile crowd of approximately 1,500 people. Many of the protest group leaders spoke that evening, but there were also some surprisingly critical speeches from previously uninvolved attorneys, clergymen, political officials, doctors, farmers, and housewives who used pleas, demands, and even threats in their efforts to persuade the commissioners to vote against a Unit 1 restart."

One activist predicted that residents would forcibly occupy the plant rather than allow it to restart. Another told the commissioners, "I resent five men in Washington holding our fate in their hands. I resent your taking three-and-a-half years to come to Harrisburg to hear us...But most of all I resent my feelings of helplessness...If ours is still a government 'of the people, by the people, for the people,' then you must know that we have spoken and said 'No Restart.'"[104] Perhaps in deference to residents' protests, the commissioners allowed December 10 to pass without a final vote. (Pressure from Governor Thornburgh and further revelations about irregularities at GPU may also have been factors in the postponement.)

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[103] The result, completed after the Supreme Court overturned the appeals court ruling, was Jon Sorenson et al., *Impacts of Hazardous Technology: The Psychosocial Effects of Restarting TMI-1* (Albany: State University of New York Press, 1987).

The utility's own blunders were the major source of hope for TMI opponents between late 1982 and the final restart decision in May, 1985. A lawsuit brought by GPU against Babcock & Wilcox alleging negligence in the reactor design backfired on the utility when witnesses for the manufacturer testifed that prior to the accident, GPU had systematically falsified operating data in order to avoid shutdown. GPU's firing of four engineers in 1983 for blowing the whistle on mismanagement of the Unit 2 cleanup process drew extensive publicity. In 1984, the utility pleaded "guilty" or "no contest" to seven of eleven federal charges that it had falsified records, and a TMI operator was convicted for cheating on operator examinations. Restart opponents cited to each of these lapses as further evidence of the utility's untrustworthiness. Ralph Nader, speaking in Harrisburg at the fifth-anniversary commemoration of the accident, asked "At what point do we determine that [GPU] has flunked as a corporation?" and suggested that the company should be dissolved.[105]

But the NRC commissioners continued to favor restart, and probably would have allowed GPU to proceed much earlier had the string of legal embarrassments not interceded. One week after a May 22, 1985, hearing in

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[104] Walsh, 142.
[105] Walsh, 153.

Washington, D.C. -- at which Governor Thornburgh, Pennsylvania Senators Arlen Specter and John Heinz, and hundreds of TMIA members made a final plea that the wishes of area residents be respected -- the Commission voted 4 to 1 to authorize the Unit 1 restart. In a statement following the vote, Commissioner James Asselstine, the only dissenter, asserted that GPU was unfit to hold a license to operate a nuclear plant and accused the other commissioners of ignoring important safety issues.

The restart vote unleashed a final spasm of local protest. TMI opponents who had found few outlets for activism during the long licensing dispute now engaged in non-violent civil disobedience. On the evening of the restart decision hundreds of demonstrators blocked the plant gates. State police arrested 82. Meanwhile TMIA, the Union of Concerned Scientists, and lawyers for the Commonwealth of Pennsylvania appealed the restart decision itself to the Federal circuit court in Philadelphia. The court issued a stay against the restart order pending arguments on the need for further hearings. This sufficed to keep the reactor cold throughout the summer, but on September 19 the judges decided the review had gone on long enough and lifted the stay. On October 2, 1985, the U.S. Supreme Court refused to hear the case. The next day, GPU finally powered up the long-idle reactor. Expressing residents' frustration at the defeat, the editors of the *Harrisburg Patriot* called the restart a "triumph of technology over the common man and common sense" and commented that "democratic rule is one of the more conspicuous victims lying in the Unit 2 rubble."[106]

Pennsylvanians concluded bitterly that the American political system had failed them. Raymond Goldsteen and John Schorr, two social researchers who spent several years interviewing residents of Newberry Township west of Three Mile Island, wrote that the accident turned the area "from an ordinary community into a fearful, angry and cynical one" where people had "soured on basic democratic processes."[107] Forty-eight percent of TMI-area residents surveyed in 1986 said they were less satisfied with government than before the accident, and 90 percent of this group attributed their dissatisfaction directly to the accident and its aftermath.[108]

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[106] October 4, 1985; Quoted in Walsh, 177.

Yet mirroring these changes was a greatly heightened level of citizen intervention in arcane, formerly hidden processes of decision-making about nuclear power technology. Inhabitants emerged from the accident "much more suspicious, more involved," in Edward Walsh's words. "They know they can be agents of change."[109] Tens of thousands of lay people in the region took part in some phase of the grass-roots effort to prevent the Unit 1 restart, whether by volunteering for anti-TMI organizations, joining lawsuits, attending hearings or rallies, voting in a referendum, speaking with journalists, or participating in social research projects.

And for the hundreds who became committed anti-nuclear activists, the six years of the restart battle worked profound personal changes. Walsh writes: "After years of struggle, [activists'] knowledge of organizational and political processes as well as energy issues had increased by degrees of magnitude. Many had become familiar with certain aspects of the political wheeling and dealing in both Harrisburg and Washington, D.C., and scores had gone to jail for their principles. The need for presentations in homes, schools, and elsewhere prompted dozens to develop into decent public speakers, while circumstances forced others to pick up considerable legal skills along the way."[110]

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[107] Goldsteen and Schorr, 174, 205.

[108] Ibid., 173.

[109] Wade Roush, "Learning from Technological Disasters," *Technology Review* (Aug.-Sep., 1993) 50-57.

The accident had, in essence, given rise to a tradition of "technological citizenship" where there was almost none before (a theme to which I will return in Chapter 6.) TMI area residents had the right to be bitter about the outcome of the restart battle; at every point possible the NRC had attempted to cut them out of the decision. But residents also had reason to be proud. They had helped delay the restart for six years, and in the process they had acquired the skills, knowledge, and confidence with which to defend themselves in any dispute related to technology or the environment. In the words of Jacques Ellul's translator John Wilkinson, "To *bear witness* to the fact of the technological society is the most revolutionary of all possible acts," and this is exactly what TMI area residents had done.[111]

Walking Away from Nuclear Power, Slowly

For the commercial light-water reactor, a technology scaled up and scattered across the American landscape more rapidly than was technically, economically, or politically wise, obsolescence seems an appropriate fate. At the time of the accident at Three Mile Island, there were 72 reactors in commercial operation in the United States and another 174 in the construction or planning stages. Today, only 110 are in operation, four are still under construction, none are planned, and several are being dismantled.[112] All of the reactors now running were ordered in 1973 or earlier, and 38 have been operating for 20 years or more, not far short of their expected 30-year lifetimes.[113] Widespread cancellations of orders for new electrical generating capacity had begun several years before the accident, but after TMI nuclear power became the target of choice for utilities making cutbacks. Scrapped nuclear plants accounted for 71 percent of the total cancelled generating capacity from 1974 to 1978, and 90 percent from 1979 to 1982.[114] By the early nineteen-eighties, the U.S. had ceded its lead in commercial nuclear technology development to Europe and Japan. As John Campbell writes in his detailed political-science study *Collapse of an Industry*, "Nuclear power suffered one of the most dramatic declines of any industrial sector in the United States in recent memory."[115]

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[110] Walsh, 189.

[111] See Translator's Preface to Jacques Ellul, *The Technological Society* (New York: Alfred A. Knopf, 1965).

[112] Campbell, *Collapse of an Industry*, 3-5. The four reactors still under construction are all owned by the Tennessee Valley Authority, whose chairman, Craven Crowell, acknowledged in Congressional hearings in March, 1994, that "If we were a private utility, we wouldn't

The reasons for this decline are complex and still controversial, but the permanent national-level shift in public attitudes toward nuclear power that occurred after Three Mile Island played an undeniable part. Skyrocketing construction costs (from an average of $817 per kilowatt of generating capacity in 1971 to $3,133 per kilowatt in 1988, in constant 1988 dollars), increasing construction times (from 5.4 years per plant in 1975 to 12.2 years in 1989), and high operating costs (nuclear plants turn out to be no cheaper to run than coal-fired plants) were among the direct causes of cancellations and the

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still be constructing nuclear plants. But we're a government agency, and we have access to capital that allows us to continue construction." Three of the four reactors may be canceled nonetheless. Danielle Droitsch, "T.V.A.'s Blighted Nuclear Romance," *The Nation* (June 27, 1994) 906-908.

[113] Matthew L. Wald, "10 Years After Three Mile Island," *The New York Times* (March 23, 1989) D1-D17; M.D. Mulheim and E.G. Silver, "Operating U.S. Power Reactors," *Nuclear Safety* (Jan.-Mar., 1993) 115-121.

[114] See Table 6.5 in Campbell, *Collapse of an Industry*, 103.

[115] Ibid., 6.

cessation of new orders.[116] But behind these statistics were important events in the political and regulatory spheres. Intolerable construction delays (with their associated finance costs) resulted partly from strong regional resistance to new plant openings and partly from the fact that new and more stringent safety regulations enacted in response to Three Mile Island "added to plant complexity and increased planning and construction costs at [the industry's] expense."[117] Higher construction and operating costs hurt utilities mainly because public utility commissions, responding to public pressure, began in the nineteen-eighties to refuse to pass these excess costs on to ratepayers.

At bottom, Three Mile Island accelerated the change in Americans' basic views on the place of nuclear power in U.S. energy production. To the most straightforward question about the desirability of nuclear power -- "Do you favor the construction of more nuclear power plants?" -- between 45 and 58 percent of Americans surveyed throughout the nineteen-seventies had answered "Yes." Immediately after the accident this level of support dropped to 39 percent, while opposition grew to 44 percent. This nearly even division of opinion has persisted ever since. When asked the very different question "Would you support the construction of a nuclear power plant in your local community?" people expressed even greater caution toward nuclear power. Those opposing local nuclear projects had begun to outnumber supporters in 1978, even before Three Mile Island, and by 1980 the ratio of opponents to supporters had grown to 3-1.[118]

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[116] See Tables 2-4 and 2-5 in National Research Council, *Nuclear Power: Technical and Institutional Options for the Future*, 31, 33.

[117] Campbell, *Collapse of an Industry*, 8.

[118] Stanley M. Nealey, Barbara B. Melber, and William L. Ranking, *Public Opinion and Nuclear Energy* (Lexington, Mass.: Lexington Books-D.C. Heath and Company, 1983) 16-23, 27-29.

At the same time, however, the percentage of the public supporting the total and permanent closure of all nuclear plants has remained low (15 to 25 percent). In the years since Three Mile Island, apparently, Americans have reached an uneasy but pragmatic accommodation with nuclear power. They recognize that a significant investment has been made in the technology and that it would be difficult, in the short term, to replace the 20 percent of the nation's electricity that comes from nuclear plants.[119] But they also hope that the existing plants will be the last to be built and that, over time, other energy sources will be found to replace nuclear power. The nuclear industry's argument that electrical generation from nuclear fission is more desirable than the burning of fossil fuels because it does not contribute to air pollution or global warming has not proved persuasive to the public, who still see nuclear power as the least-desirable energy option among the choices of coal, oil, natural gas, and conservation.[120]

At the heart of the public's cautious attitude toward nuclear power is skepticism about the adequacy of reactor safety systems. Media coverage of nuclear safety issues after Three Mile Island (network news broadcasts devoted more time to the subject in the two weeks after the accident than in the previous 35 years of nuclear energy's history, one study found[121]) helped give structure and focus to citizens' concerns. Polls taken in 1979 found that 82 percent of the public had been either "somewhat" or "deeply" disturbed by the accident. GPU and Babcock & Wilcox received the most negative ratings for their parts in the accident, though 55 percent of those polled believed operator error was most to blame. CBS and the Harris polling organization both asked respondents whether they believed that the Three Mile Island accident was a freak event or whether they thought more nuclear accidents were likely. Only 37 and 29 percent, respectively, said the accident was unusual enough that a similar event was unlikely; 50 and 69 percent believed a recurrence was probable.[122]

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[119] A 1979 Gallup poll found that a majority of Americans (56 percent) believed that the energy shortage that might result from the shutdown of all nuclear reactors was a bigger risk to the nation than the presence of those reactors. Ibid., 89.

[120] Ibid., 129-135; Eugene A. Rosa, et al., "Public Views Toward National Energy Policy Strategies: Polarization or Compromise?" in William Freudenburg and Eugene A. Rosa, eds., *Public Reactions to Nuclear Power: Are There Critical Masses?* (Boulder, Colorado: Westview Press, 1984) 69-93.

[121] Robert L. DuPont, "Understanding Fear of Nuclear Power," (1980), cited in Nealey, et al., 5.

When the National Science Foundation asked people in 1979 whether they believed that harmful consequences were likely to come from the construction of more nuclear plants, 78 percent said yes, and the largest group of these respondents, 36 percent, said they feared most the possibility of meltdown or human error leading to a catastrophic accident.[123] In another poll, the percentage of people who agreed with the statement "The thing that worries me the most about nuclear plants is the question of safety" jumped from 70 percent in 1978 to 86 percent in 1979.[124] These worries have grown even stronger in the post-Chernobyl era; in a 1990 poll, three-quarters of Americans said they believed nuclear energy was the most dangerous way to generate electricity.[125]

Capitalizing on this new skepticism, organized anti-nuclear groups successfully placed nuclear energy referendums on a number of state ballots in the nineteen-eighties. The outcomes of these votes reflected Americans' compromise solution on the phaseout of nuclear power:

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[122] Ibid., 86-88.

[123] 31 percent mentioned low-level radioactive leaks, and 13 percent pointed to radioactive waste disposal problems. Ibid., 67-68.

[124] Ibid., 75.

[125] National Research Council, *Nuclear Power: Technical and Institutional Options for the Future*, 58.

- A 1980 Oregon initiative requiring local referenda before the siting of new nuclear plants passed by 53 to 47 percent.

- A 1981 Washington state initiative requiring voter approval before the Washington Public Power Supply System (WPPSS, universally known to Washingtonians as "Whoops") could issue bonds for the construction of nuclear and other power facilities passed by 58 to 42 percent. (WPPPS eventually defaulted on existing bonds and was forced to suspend construction on five nuclear plants in the state.)

- A 1982 ballot question in Massachusetts restricting nuclear plant construction and radioactive waste disposal passed by 2-1.

- A 1986 initiative in Oregon to require the shutdown of the Trojan nuclear plant near Portland was rejected by nearly 2-1.

- A 1987 initiative in Maine to shut down the Maine Yankee reactor failed by a similar margin.

- A 1988 ballot question that would have resulted in the shutdown of Massachusetts nuclear plants also failed by 2-1.

- Also in 1988, a county initiative in Sacramento, California, to shut down the trouble-ridden Rancho Seco nuclear plant lost by a slim margin, 50.3 to 49.7 percent. (The plant was later closed down for safety reasons).[126]

In state voting, ballot issues creating broad regulations or democratic approval mechanisms for the management of nuclear power fared far better than those aimed narrowly at the shutdown of particular existing plants. Even taking into account the disparities in campaign funding and advertising available to the two sides in each ballot question (nuclear energy proponents in the 1980 Oregon initiative, for example, outspent the initiative's supporters by 18 to 1[127]), it seems clear that American voters are reluctant to take sweeping action to eliminate nuclear power as an energy source for the present. As public-beliefs researchers Stanley M. Nealey, Barbara B. Melber, and William L. Rankin wrote in 1983,

> Little by little, more people are going to know more about nuclear technology and the issues surrounding nuclear-power development. The usual course of public acceptance of a new technology, from automobiles at the turn of the century to microwave ovens in the nineteen-seventies, involves initial fear and skepticism. This gives way to eventual wide acceptance, if the technology delivers important benefits *and if the period of its introduction passes without one or more catastrophic mishaps.* The Hindenburg disaster brought the development of dirigibles to a sudden halt though their popularity had been growing prior to the disaster and though technical developments, such as the use of helium, would have overcome the fire hazard. The accident at Three Mile Island, by far the most widely known event in the history of commercial nuclear power, seems not to have been perceived by most people as the catastrophic mishap that justifies the end of nuclear power.[128]

Nealey, Melber, and Rankin were unable to foresee, of course, the Chernobyl disaster and the record-high levels of opposition to nuclear construction projects that followed it (70 percent in 1986).[129] While 38 of the plants under construction at the time of the Three Mile Island accident have since come on-line, levels of opposition like this and the drawn-out siting and licensing disputes they guarantee mean that nuclear power is, in fact, approaching its permanent demise. A nuclear plant would be the last option considered by a utility thinking of adding new generating capacity. Even existing nuclear plants are giving owners bigger and bigger headaches, as on-site storage space for spent fuel runs low and as questions loom about how to decommission and unbuild old nuclear reactors safely. As Alvin Weinberg predicted after Three Mile Island, the present reactors will be allowed to run their course, but no further growth will be tolerated: a remarkable story, unparallelled among the large technological systems of the twentieth century.

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[126] David P. Schmidt, *Citizen Lawmakers: The Ballot Initiative Revolution* (Philadelphia: Temple University Press, 1989) 77-95; Betty H. Zisk, *Money, Media, and the Grass Roots: State Ballot Issues and the Electoral Process* (Newbury Park, Calif.: Sage Publications, 1987) 104-5, 126-27, 200, 210-11.

[127] Zisk, *Money, Media, and the Grass Roots,* 105.

[128] Nealey et al., *Public Opinion and Nuclear Energy,* 181-82. Emphasis added.

It would be unfair to overlook another important outcome of the accident: the improvements made to LWR safety systems. Equipment upgrades mandated by the NRC included the redesign of display consoles and control room layouts, the installation of instruments to measure core coolant levels directly, and the replacement of pipes and valves with new models that function reliably under a broader range of operating and emergency conditions. Utilities have banded together to form the Institute for Nuclear Power Operations, which runs an operator training academy and audits each plant annually for adherence to quality standards. Satellite links installed at each reactor control room now relay 60 categories of real-time telemetry, including reactor pressure, coolant flow, temperature, and outside weather, to NRC headquarters in Washington, and the Commission employs resident inspectors at each site. NRC officials have become less reluctant to shut down plants for poor management, at times idling up to 10 percent of the nation's nuclear facilities. The number of unplanned, automatic reactor scrams -- an indirect measure of maintenance quality and operator diligence -- dropped from 7.4 per plant per year in 1980 to 2.7 in 1987.

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[129] Van der Pligt, *Nuclear Energy and the Public,* 7.

But whether all this means that "America's nuclear option potentially can be even stronger," as Berkeley nuclear engineer Thomas Pigford has suggested, is highly doubtful.[130] Former NRC safety expert Robert Pollard, now a member of the Union of Concerned Scientists, told the *New York Times* in 1989 that "it's beyond dispute that the plants are safer. The question is, how much safer, and is that enough?"[131] During the nineteen-eighties utilities reported more than 30,000 mishaps at U.S. nuclear reactors, some minor, some alarming. Examples drawn at random from the pages of the Department of Energy publication *Nuclear Safety* include the following:

- On February 26, 1980, in an event reminiscent of Three Mile Island, a malfunctioning instrument panel in the control room of the Crystal River Unit 3 reactor in Florida caused the reactor's pressurizer relief valve to open for two hours, spilling 40,000 gallons of radioactive coolant water onto the floor of the containment building. The reactor was safely shut down.[132]

- On January 25, 1983, an unexpected reactor shutdown at the Maine Yankee plant caused the plant's auxiliary cooling system to kick in, filling the steam generator and associated piping with cold water so quickly that "water hammer" and thermal stress cracking resulted in a feedwater line break. 12,000 gallons of radioactive water was dumped into the containment building.[133]

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[130] Thomas Pigford, "Three Mile Island: The Good News," *The New York Times* (March 28, 1989) A21.

[131] Wald, "10 Years After Three Mile Island," D17.

[132] William R. Casto, "Selected Safety-Related Events Reported in March and April, 1980," *Nuclear Safety* (Jan-Feb., 1984) 115-16.

- On December 9, 1986, an isolation valve on one of the steam generators at the Surry Unit 2 plant in Virginia stuck closed. High pressure inside the generator caused a feedwater pipe to burst and fly loose. The superheated water and steam escaping into the containment building severely burned eight workers. Four subsequently died.[134]

By 1989, only 24 reactors had undergone all of the safety changes required in the NRC's Three Mile Island Action Plan. Massachusetts Representative Edward J. Markey, a long-time critic of the nuclear industry, commented that "The TMI Action Plan was a major test of the commitment of the NRC to public health and safety. It is a test which the NRC has clearly failed."[135] And no matter how many pieces of equipment are overhauled or replaced, the fundamental design flaws of LWRs remain. As Perrow demonstrated in *Normal Accidents*, and as a growing number of nuclear engineers concur, the "defense-in-depth" strategy for mitigating loss-of-coolant accidents in large nuclear reactors is ultimately self-defeating. Multi-layered safety systems simply work against Murphy's Law. If something can go wrong, it will, and the more things that can go wrong, the harder it is to isolate each and prevent a system accident. As Perrow wrote, "We may have reached a plateau [in our understanding of complex nuclear reactor systems] where our learning curve is nearly flat."[136]

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[133] G. A. Murphy, "Selected Safety-Related Events Reported in October, November, and December, 1986," *Nuclear Safety* (April-June, 1987) 240.

[134] William R. Casto, "Selected Safety-Related Events Reported in March and April, 1980," *Nuclear Safety* (July-Aug., 1980) 516-517

[135] "Nuclear Safety Goals Are Not Met," *The New York Times* (March 17, 1989) D4.

Some scientists advocate leaping beyond this plateau to a new generation of reactors known as "inherently safe" or, more modestly, "advanced" or "evolutionary" reactors. Rather than adding complexity to the old defense-in-depth mechanisms, these reactors would be theoretically incapable of melting down as a matter of design. Engineers estimate that plants with passive cooling mechanisms, relying on gravity and convection for the circulation of coolant, could be built with 60 percent fewer valves, 35 percent fewer pumps, and 75 percent less piping than conventional LWRs, making them less vulnerable to the complex interactions that lead to system accidents. Other designs reduce or eliminate the possibility of meltdown by building in "passive decay heat removal systems" and repackaging the uranium fuel itself into impermeable, graphite-covered spheres which radiate away decay heat more efficiently.[137] A gas-cooled German reactor incorporating the latter feature produced 3 billion kilowatt-hours of electricity before it was shut down for financial reasons in 1989.

The attraction of "inherently safe" reactors is obvious. But a 1992 report on advanced reactor technology by the National Research Council of the National Academy of Sciences concluded that while there is "a distinct advantage to passive containment cooling for preventing containment failure... dependence on passive safety features does not, of itself, ensure greater safety, especially given the potential effects of earthquakes, design errors, inspectability, manufacturing defects, and other subtle failure modes."[138] Given the public's strong antipathy toward nuclear power of any variety and the federal government's tepid support for research and development on new controlled-fission designs, it seems unlikely that a new, safer generation of reactors will be ready in time to replace today's aging plants. Nor will a permanent underground radioactive-waste depository be in operation before the spent-fuel pools at each plant site have filled to capacity.

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[136] Perrow, *Normal Accidents*, 11-12.
[137] These spheres would also be safer to store as spent fuel than conventional fuel rods.

Even without another major accident, then, the nuclear industry faces troublesome decades ahead. But certain mistakes of the past will not be repeated. As Alvin Weinberg recognized even before Three Mile Island, "The public perception and acceptance of nuclear power appears to be the question we missed rather badly in the very early days [of civilian nuclear power development]. This issue has emerged as the most crucial question concerning the future of nuclear energy."[139] Three Mile Island and Chernobyl cost the U.S. nuclear establishment its special immunity from broader social and political concerns. Each future step in the technology's development, whether toward death or attempted rebirth, will now be challenged and shaped by people representing a much wider set of interests than were ever involved in nuclear issues before Three Mile Island.

The mechanisms for this kind of public participation are still crude, coming into being only piecemeal as local citizens' groups win isolated battles for influence. But these groups do have a powerful historical argument at their disposal: Twice in the last fifteen years, sophisticated safety systems have failed to prevent unexpected human errors and machine failures from coming together to cause disastrous reactor accidents. (There was no loss of life at Three Mile Island because the last safety barrier, the reactor vessel itself, did not rupture; events at Chernobyl went much farther, as Chapter 5 will explain.) Citizen knowledge of these disasters cannot be taken away. Its significance can be argued, but not denied.

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[138] National Research Council, 91-155; quotation from p. 136.

[139] Alvin Weinberg, "The Maturity and Future of Nuclear Energy," *American Scientist* (64: 1976) 16-21.

The people of Three Mile Island lived through a kind of terror never before experienced in this country and were repaid for their trouble by the nuclear establishment's campaign to nullify their roles as citizens and decisionmakers. But that campaign, while successful for General Public Utilities in the short run, did nothing to improve nuclear power's public profile or to prolong the technology's existence. The residents of southeastern Pennsylvania might someday wish to have the decommissioned Three Mile Island facility preserved as an historical monument, one as significant in its own way as the Civil War battlefield markers that dot the region. It will be a testament not just to the nation's failed dreams of cheap, abundant nuclear energy, but to the inroads a skeptical and organized citizenry has made against the political power of large technological systems.

Chapter 4

RUNAWAY REACTION
Knowledge, Control, and Democracy After Bhopal

For agony and spoil
Of nations beat to dust,
For poisoned air and tortured soil
And cold, commanded lust,
And every secret woe
The shuddering waters saw --
Willed and fulfilled by high and low --
Let them relearn the Law.

—Rudyard Kipling,
"Justice" (1918)

On December 2, 1984, Anees Chishti was up late in his room at the Hotel Nalanda in the old part of Bhopal. A 53-year-old journalist with university degrees in chemistry, Chishti was in the city to gather information for a story on the upcoming parliamentary elections.

"I was trying to get one of the foreign stations on the radio at about 2:30 a.m. when I felt some choking in my throat," he said later. "I thought it was some ordinary case of bad throat or something. I tried to get some cough syrup but then I realized that it was something much more than that. There was a burning sensation in the eye. I somehow opened the door of my room. First I thought it was a hotel problem. I went out. I was running for some open space where I could get relief but I could get relief nowhere. I felt this was something like gas. So I dressed up, took my identity card, filing authority, the money I had because I didn't know if I would come back alive, or where I would be.

"When I came out, I saw hordes of people moving towards some direction. I was new to Bhopal city, I didn't know all the routes. Nobody was in a position to tell me which road led to the Paintalees Bangle area, where I had some friends, some access to communication. Anyway, I walked. Some landmarks were there. And that was a ghastly experience. I saw ladies, almost undressed, straight out of the bed in petticoats, children clinging to their breasts, all wailing, weeping, some of them vomiting, some of them vomiting blood, some falling down, I now presume falling dead. It was a sight. And when I was passing through Kamala Park it was a very bad situation, people trying to enter temples...they were falling dead, family members were leaving their own family members and running for safety.

"My own rationality was challenged for the first time in my life -- on that stretch of four kilometers. For a while I also thought some religious thoughts that might perhaps save me. But then I was back to my rational thinking very soon. My eyes were burning. In that condition I reached the *Indian Express* office. Nobody knew what was happening. Soon people started pouring in asking for blankets, sheets, water, all sorts of things. I gave them water, people started putting water into their eyes, but having been a chemistry student myself I was not very sure of what the effect of water would be on the gas, because it was a gas, after all. And nobody was telling wherefrom the gas was coming. Nobody I have spoken to actually heard an announcement. The sky was clear, as I was passing I could see the stars. I didn't smell anything, maybe because of panic."[1]

Chishti's lungs and those of thousands of others in Bhopal were partially eaten away that night by leaking methyl isocyanate gas, a component of the commercial pesticide Sevin. Despite his injuries, Chishti made his way by dawn to the source of the corrosive cloud, a Union Carbide plant two miles north of the city's central railroad station. There he obtained interviews with the plant's managers and composed the first of dozens of newspaper dispatches he would file on the disaster over the coming months. The story that emerged from Chishti's work and that of other journalists was one of scarcely-credible devastation. The Bhopal gas leak, history's most lethal industrial accident up to that time, killed more than 3,000 people and injured 200,000, quickly becoming an international symbol of corporate callousness and the hidden threat chemical factories pose to host communities. Needless to say, the elections Chishti was to have covered were postponed.

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[1] Anees Chishti, *Dateline Bhopal: A Newsman's Diary of the Gas Disaster* (New Delhi: Concept Publishing, 1986) 7-8.

Nothing that has occurred since the gas disaster can make up for the victims' suffering, which is the true ongoing story of Bhopal. Even payments far larger than the $470 million settlement reached between Union Carbide and the government of India in 1989 would not bring back the dead, cure the survivors' disabilities, or restore the social and economic fabric of the city. Yet the shock and dismay the catastrophe caused among lay citizens around the world also fueled political changes that have turned the traditional methods of chemical-hazard control on their heads. Groups in India have organized to keep new industrial threats out of their communities, and regulations enacted in the U.S. after Bhopal have put power in the hands of citizens by requiring manufacturers to disclose information on the kinds and amounts of toxic substances they release into the environment each year. These "right-to-know" laws are designed to prevent chemical disasters by giving industries' neighbors the means to be vigilant -- means unavailable to the people of Bhopal, who had no inkling that Union Carbide's "plant medicine" was a deadly toxin or that it might one day escape the facility. This sharing of technological control, as it spreads to other industries and nations, helps to honor -- though not justify -- the Bhopal victims' loss.

It is a troubling irony, however, that Bhopal's most important political effects occurred in the United States and other Western nations, not in India. No other technological crisis abroad has led to such extensive changes in U.S. law, industrial practice, and community-industry relations. But only an unfaithful account of the disaster could pretend that Bhopal's social and political aftermath in India has been, on the whole, encouraging or beneficial. Like the former Soviet republics, India is a nation facing numerous economic, ecological, and ethnic problems, so that even a catastrophe on the horrifying scale of a Chernobyl or a Bhopal must compete for attention with numerous other pressing matters. Grassroots Indian responses to the disaster were handicapped by an unresponsive government, low literacy rates, people's necessary preoccupation with economic survival, and plain apathy.

The emphasis on responses in the United States in the later sections of this chapter is a product of the fact that the American public, already sensitized to industrial hazards by incidents like Love Canal and Three Mile Island, was better able to act for increased citizen involvement in decisions about chemical technology. Moreover, the U.S. political system was not consumed, as India's was, by the need to provide medical and social relief for the disaster victims and by a drawn-out dispute over matters of liability and compensation. If Americans living near chemical facilities are significantly safer today than they were ten years ago, it is because thousands of Indian citizens died through the negligence of an American corporation.

Just two weeks before the Bhopal leak, the explosion of four liquefied-natural-gas tanks outside Mexico City killed more than 500 people. The *Wall Street Journal* labeled the accident "Mexico's Three Mile Island," and similarly, in the debate over Bhopal's meaning for industrial communities in the U.S., Three Mile Island was the central metaphor and historical reference point. James Speth, president of the World Resources Institute and chairman of the Council on Environmental Quality under President Carter, predicted that "Bhopal will become the chemical industry's Three Mile Island -- an international symbol deeply imprinted on public consciousness...Just as Three Mile Island spurred a thorough assessment of the safety of nuclear power, Bhopal will bring justifiable demands that hazardous facilities in the chemical industry be designed, sited, and operated so that nothing even close to Bhopal can ever happen again."[2] Michael Heylin, editor of the industry journal *Chemical and Engineering News*, agreed that "the worldwide chemical industry has been changed forever by Bhopal," but his view of Three Mile Island's legacy was clearly different from Speth's. "The way Carbide has handled things so far has removed the remote possibility that Bhopal would have the same crippling effect on the chemical industry that Three Mile Island had on the future of nuclear power," he wrote.[3]

As an undisputed debacle for the nuclear industry, the Three Mile Island case made the arguments on both sides of the Bhopal debate immediately clear. If chemical manufacturers wanted to avoid the fate of their compatriots in nuclear power business, they would have to sacrifice some measure of control over their industry. But how much? What environmentalists and citizen activists saw as "justifiable demands" for new controls over chemical hazards were viewed by industry representatives as "crippling." This clash was at the core of the fight for right-to-know laws in the U.S., and it continues to characterize the relationship between manufacturers and the local citizens' groups now using toxic-release data to press for safety improvements and pollution reduction.

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[2] Philip Shabecoff, "Officials Tell a House Hearing that Plant in West Virginia is Safe," *The New York Times* (Dec. 13, 1984).

[3] Michael Heylin, "Bhopal: A C&EN Special Issue," *Chemical and Engineering News* (Feb. 11, 1985) 14-15.

This chapter will investigate how the particulars of the Bhopal accident itself -- its origins in political and technical decisions made at a far remove from the people actually harmed by the disaster -- strengthened the conviction among citizens and lawmakers that information about chemical hazards, and hence control over those hazards, must be shared more democratically. After recounting the history of Union Carbide's operations at Bhopal and the emergence of the social conditions that made the disaster possible, I will describe the leak itself and its immediate effects on the city's population. Next, I survey the range of Indian reactions to the disaster, including the swift response of voluntary citizens' groups, the controversy surrounding the legal case against Union Carbide, and the growth of technology resistance movements in scattered Indian communities. Ending the chapter is an account of the reaction to the disaster in U.S. chemical communities -- especially West Virginia's Kanawha Valley, home to the Bhopal facility's sister plant -- and a history of the enactment and use of right-to-know laws governing chemical facilities. While limited in scope, these laws have fundamentally altered the balance of power between U.S chemical producers and their host communities.

Organic Chemistry Comes to Bhopal

Chemistry, an ancient science, is also one of the oldest modern industries. As early as 1780 chemists were mixing sulfur, saltpeter, and air in large lead-lined chambers to produce sulfuric acid, an agent in the manufacture of bleaching powders and soda.[4] By 1850 French and British sulfuric acid factories already incorporated "most of the design principles of modern engineering."[5] Three important developments in the second half of the nineteenth century -- the discovery of synthetic coal-derived dyes, the invention of nitration methods for organic cellulose and glycerin compounds, and the use of dynamos to manufacture electrochemicals such as chlorine gas and acetylene -- formed a base for the industry's tremendous growth after 1900. Union Carbide Company, founded in 1898 to produce acetylene for home and street lighting, became one of the largest chemical manufacturers in the United States when it merged in 1917 with three other firms making electric arc lamps, dry cell batteries, oxygen for acetylene torches, and acetylene lamps for automobiles.[6] As the organic chemistry revolution began in the nineteen-twenties and thirties, Union Carbide commercialized Vinyon, a competitor to Du Pont's new synthetic fiber Nylon (of which more later).[7]

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[4] L.F. Haber, *The Chemical Industry During the Nineteenth Century* (Oxford: The Clarendon Press, 1958) 3-5.

With foreign supplies of natural rubber cut off during World War II, the crash program to create a U.S. synthetic rubber industry was "the chemical equivalent of the Manhattan Project," in the words of John Kenly Smith, a historian of the chemical industry.[8] Union Carbide's research on butadiene, an acetylene derivative similar to the isoprene molecules that make up natural rubber, helped synthetic rubber production grow from zero at the beginning of the war to 800,000 tons per year by its midpoint. (At the same time, Union Carbide became part of the real Manhattan Project as manager of a uranium gaseous-diffusion plant for atomic bomb fuel at Oak Ridge, Tennessee.) After the war, the synthetic polymers that had proved good substitutes for rubber, glass, brass, aluminum, and other strategic materials evolved into a vast array of polyethylene-based consumer products, including Union Carbide's Glad plastics.

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[5] Historian John Kenly Smith, quoted in Stu Borman, "Conference Offers Insights on Challenges Facing Science Historians," *Chemical and Engineering News* (Aug. 6, 1990) 26.

[6] David Dembo, et al., *Abuse of Power: Social Performance of Multinational Corporations: The Case of Union Carbide* (New York: New Horizons Press, 1990) 12-13.

[7] David Hounshell and John Kenly Smith, Jr., *Science and Corporate Strategy: Du Pont R&D, 1902-1980* (New York: Cambridge University Press, 1988) 386. It was at this time that Union Carbide precipitated what has been called "the worst occupational health disaster in American history," the Hawk's Nest Tunnel Incident. Between 1930 and 1932 Union Carbide employed 5,000 men to drill a three-mile tunnel through Gauley Mountain in West Virginia. High silica content was discovered in the rock , and the construction project became an unreported mining project as well, since the company used silica in its plant at Alloy. Union Carbide knew of the health threat posed to workers by silica dust but took few precautions. Some 700 workers died of silicosis within five years of the tunnel's completion. The case was eventually settled out-of-court for less than $130,000, but figured prominently in Congressional deliberations strengthening occupational safety regulations. See Martin Cherniack, *The Hawk's Nest Incident: America's Worst Industrial Disaster* (New Haven: Yale University Press, 1986).

[8] Borman, 28.

The birth in the nineteen-sixties of the Green Revolution -- the campaign in many Third World nations, including India, to increase food production through the mechanization of agriculture and the use of high-yield grains and chemical pesticides and fertilizers -- created a massive new market for organic chemicals. Supported by government subsidies, pesticide use tripled in India between 1956 and 1970.[9] Union Carbide, which had been doing business in India since 1905 through its subsidiary Union Carbide India Limited (UCIL), was ideally placed to profit from this trend. Though more than half of UCIL's revenue in India came from the sale of its Eveready batteries, the company had used parent Union Carbide's advanced technology to become a leader in several other capital-intensive manufacturing sectors, including specialized metals, gases, and plastics. The company's Agricultural Products Division, headquartered in Bhopal, was a welcome addition to the Indian economy when it opened in 1969. "If you want to buy something and you're told it's a Union Carbide product, you just go and buy it," said Gopal

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[9] Mark N. Wexler, "Learning from Bhopal," *Midwest Quarterly* (Autumn, 1989) 113; Paul Shrivastava, *Bhopal: Anatomy of a Crisis* (Cambridge, Mass.: Ballinger Publishing Company, 1987) 39.

Behari, an adviser at the Indian Investment Center in Delhi. "It was the same for a pesticide plant. It came from them. We expected it to be good."[10]

Bhopal, in the early nineteen-seventies, was already a city suffering from "industrial indigestion."[11] For a century before Indian independence in 1947, the city was ruled by Moslem landowners with little interest in modernization. When the Indian government chose Bhopal in 1956 as the capital of the state of Madhya Pradesh and in 1959 as the site of a gigantic state-owned electrical works, the city's primitive infrastructure for transportation, communication, education, and public health came under severe strain. As the Green Revolution kicked in and agricultural employment fell behind rural population growth, meanwhile, the rural unemployed sought work in cities, swelling Bhopal's population from 102,000 in 1961 to 670,000 in 1981 (and to 900,000 in 1991).[12] With transportation difficult and government housing scarce and overpriced, makeshift shantytowns accreted around factories and other centers of employment, including the Union Carbide plant. Though a lively and intricate social organization helped offset dismal material conditions in the shantytowns, residents knew little -- and could do even less -- about the dangers posed by the industrial plants in their midst.

Proving how thoroughly Mohandas Gandhi's vision of an Indian economy based on small-scale, artisanal production had been repudiated after independence, industrialization in Bhopal and elsewhere had proceeded too fast for health and environmental safeguards to keep pace. Shantytown residents lacked the clout to merit protection even under existing regulations.

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[10] Barry Newman, "Death in Bhopal: Compensation Seems Not Quite the Point," *The Wall Street Journal* (Dec. 19, 1984) 1, 20.

[11] Lois R. Ember, "Technology in India: An Uneasy Balance of Progress and Tradition," *Chemical and Engineering News* (Feb. 11, 1985) 64.

[12] Shrivastava, 57-59.

A development plan approved for Bhopal in 1975 legally required "obnoxious industries," including pesticide manufacturers, to relocate to an industrial zone 15 miles away from residential areas.[13] But the plan was never enforced, and the shantytowns continued to grow. Hut owners in Jaiprakash Nagar, a neighborhood just across the street from Union Carbide, thought the facility was making "medicine for the crops" or "some kind of powder." Said one resident, "We were never told anything about poison, by the company or the government."[14] Small leaks from the plant occasionally caused nausea and other symptoms, but the plant's neighbors "were never in a position to protest because they had illegally set up their houses," explains Kim Laughlin, an American anthropologist who spent eighteen months working with voluntary citizens' groups in Bhopal. "They continually feared that the slums, not the plant, would be relocated."[15]

During the first five years of its existence, from 1973 to 1978, the Bhopal plant only formulated and packaged pesticides, mixing together ingredients imported from Union Carbide plants outside India. But high shipping costs, pressure from the Indian government to reduce imports, and growing competition from smaller firms with low-cost manufacturing capacity led UCIL to plan its own facilities for the production of methyl isocyanate.[16] MIC is an intermediate product in the synthesis of carbaryl, an insecticide which the company markets under the brand names Sevin and Sevimol. When it introduced the pesticide in 1957 Union Carbide had made carbaryl by reacting phosgene (used as a chemical weapon during the First World War) with the compounds alpha-naphthol and then methylamine, with 1-naphthol chloroformate as an intermediate product. But in 1973 the company juggled this process, first reacting methylamine with phosgene to create MIC, then adding alpha-naphthol to make carbaryl. MIC was much more reactive than chloroformate and therefore harder to handle safely, but the company considered the new process superior because MIC could also be used at its U.S. plants to produce Temik and other carbamate-based pesticides.[17] Though there was no such reason to favor the MIC process at the Bhopal plant, the process was the natural choice since the technology could be copied directly from Union Carbide's existing MIC facility in Institute, West Virginia. In October, 1975 -- two months *after* Bhopal municipal officials had ruled on the relocation of "obnoxious industries" -- UCIL received a permit from the state government to build the MIC plant on its eighty-acre site near the heart of Bhopal.

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[13] Robert Reinhold, "Disaster in Bhopal: Where Does Blame Lie?" *The New York Times* (Jan. 31, 1985) A1, A8.

[14] Robert Reinhold, "Slum Dwellers Unaware of Danger," *The New York Times* (Jan. 31, 1985) A8.

[15] Laughlin is an assistant professor in the Program in Science and Technology Studies at Rensselaer Polytechnic Institute in Troy, New York. She kindly provided me with a copy of her 1993 unpublished manuscript entitled "Rehabilitating Science, Imagining Bhopal." Quoted with permission.

[16] Wexler, 114; Reinhold, A8.

By 1979 MIC production was underway, but conditions at the Bhopal plant differed ominously from those at the prototype facility in Institute. Though the usual 40 percent limitation on foreign equity in Indian companies had been waived in Union Carbide's case -- the American parent owned 50.9 percent of UCIL, Indian investors and the government the other 49.1 percent -- the firm was not exempt from Indian "indigenization" laws requiring that the plant be designed and built using local equipment, materials, and workers.[18] As a result, the quality of the plant's construction did not meet U.S. safety standards. Government guidelines also encouraged a labor-intensive design, one dependent on manual rather than automatic safety controls at many points in the production process. These policies might have been benign had Union Carbide's visions of profitability for its new facility been realized, but 1979 was also the year when "the bottom fell out of the agricultural pesticide industry."[19] Dwindling subsidies and favorable weather drove Third World pesticide use rapidly downward. The Bhopal plant, with the capacity to make 5,000 tons of pesticides per year, produced 1,647 tons in 1983 and 2,308 in 1984, contributing only 8 percent of UCIL's total revenues.[20]

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[17] Ward Worthy, "Methyl Isocyanate: Chemistry of a Hazard," *Chemical and Engineering News* (Feb. 11, 1985) 27-32.

[18] Stuart Diamond, "Plant Had to Be Locally Designed and Operated," *The New York Times* (Dec. 13, 1984).

As it began to seem that sales of Sevin would never be great enough to pay off UCIL's $24 million investment in the Bhopal MIC facility, the plant's management structure began to crumble. Six different directors ran the plant between 1979 and 1984. Of the twenty UCIL engineers who spent a year at Institute in 1978 training to become the subsidiary's technical experts on MIC, all but four had resigned from the Bhopal plant by 1984 amidst economic losses and plummeting morale.[21] At the same time, layoffs among the blue-collar staff in 1983 reduced the number of operators on each rotating shift at the MIC plant from eleven to six; in maintenance, from ten to six; and in the control room, from two to one. As a former project engineer at the plant put it, "The whole industrial culture of Union Carbide at Bhopal went down the drain."[22] In the three years before the final catastrophe, small MIC and phosgene leaks killed one worker and injured at least 21.[23] Hoping to cut its losses, UCIL put the plant up for sale.

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[19] Wexler, 115.

[20] Robert Reinhold, "Union Carbide of India: Image is Shattered," *The New York Times* (Dec. 12, 1984) A9.

[21] Wexler, 115-16; Shrivastava, 49; Sheila Jasanoff, "The Bhopal Disaster and the Right to Know," *Social Science and Medicine* (Vol. 27, No. 10, 1988) 1115; Praful Bidwai, "Plant Undermanned, Run Down," *Bhopal: Industrial Genocide?* (Hong Kong: Arena Publications, 1985) 72-73.

[22] Stuart Diamond, "The Bhopal Disaster: How It Happened," *The New York Times* (Jan. 26,

It was at this time that a dangerous combination of knowledge, denial, and ignorance of the plant's hazards set in. Union Carbide executives at the company's U.S. headquarters knew enough about Bhopal's management problems to dispatch a three-member inspection team in 1982. Their report concluded that unstable management and nearly a dozen major technical and maintenance deficiencies had created "a higher potential for a serious accident or more serious consequences if an accident should occur." The team "strongly recommended" that the spray system on the plant's periphery, designed to throw up a curtain of water to prevent chemical clouds from escaping the premises, be strengthened.[24] UCIL received the report but ignored the recommendation, and the parent company never undertook a follow-up investigation, asserting that "safety is a local responsibility."[25] In September, 1984, three months before the disaster, another safety audit at the company's Institute plant warned that a runaway reaction resulting in "catastrophic failure" could occur if even a small amount of water entered the MIC storage tanks, but this warning was not shared with managers at Bhopal. "It was not immediately apparent to me that it would have been helpful," explained Jackson Browning, the company's director of health, safety, and environmental affairs.[26]

1985) A1, A6.

[23] Wexler, 118-118.

[24] Diamond, "The Bhopal Disaster: How It Happened," A6.

[25] Stuart Diamond, "Union Carbide's Inquiry Indicates Errors Led to India Plant Disaster," *The New York Times* (Mar. 21, 1985) A1.

[26] Robert E. Taylor and Ron Winslow, "Union Carbide Internal Report Warned of Hazards at U.S. Plant, Waxman Says," *The Wall Street Journal* (Jan. 25, 1985) 2.

With high employee turnover the rule at the Bhopal plant, meanwhile, few workers bothered to read the company technical manuals that mentioned MIC's lethal effects. "The management said MIC could give you a rash on your skin or irritate your eyes. They never said it could kill you," one worker reported after the disaster.[27] Said another worker with 11 years' experience at the plant, "I was never told that there were such dangerous chemicals inside the factory. If I knew, I would not have worked there. When we worked there, our eyes used to hurt and our skin itched, but who ever knew that such a disaster could happen?"[28] No one in India knew, apparently. Though Union Carbide had established a U.S. toxicology laboratory as early as 1935 and had done more research on MIC's toxicity than any other organization, the results were trade secrets so well protected that even plant managers at Bhopal admitted their ignorance of the chemical's dangers.[29] "No one at this plant thought MIC could kill more than one or two people," said Kamal Pareek, an engineer who had helped build the facility.[30] And at Union Carbide headquarters, where all major financial and safety decisions about the Bhopal plant were made, no one recognized the true extent of the Bhopal staff's deficiencies or took the trouble to rectify them. "Union Carbide had its finger on the pulse of the Bhopal plant all the time. They just didn't appreciate the information they were getting," Pareek said.[31]

The disaster, in sum, would reveal "a disturbing pattern of ignorance among those exposed to risk and more or less informed indifference among those with the power to prevent the accident from happening," as Sheila Jasanof, a sociologist and legal expert, has written.[32] It was this disparity in levels of knowledge and control -- not any intrinsic technical incompetence in India, as some analysts have suggested -- that made the Bhopal catastrophe possible. In the months after the disaster, the rueful consensus in the West was the one expressed by political scientist Richard Worthington: "It is all too easy to transfer hardware from industrialized to developing nations, but just about impossible -- and unethical -- to impose the political-economic structures, the regulatory apparatus, and western-scientific world view that are necessary for the hardware to work efficiently and safely."[33]

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[27] Stuart Diamond, "Many at Plant Thought MIC Was Chiefly a Skin-Eye Irritant," *The New York Times* (Jan. 30, 1985) A6.

[28] Bhopal Group for Information and Action, *Voices From Bhopal* (Bhopal, India: Aadarsh Printers & Publishers, 1990) 8.

[29] Hounshell and Kenly Smith, 562-63; Shrivastava, 50.

[30] Diamond, "Many at Plant Thought MIC Was Chiefly a Skin-Eye Irritant."

[31] Stuart Diamond, "U.S. Company Said to Have Had Control in Bhopal," *The New York Times* (Jan. 28, 1984) A7.

Such statements were well-meaning but wrong. India is a technologically sophisticated nation with the third-largest pool of scientific and engineering expertise in the world. But understandably, few talented Indian engineers elected to stay at the Bhopal plant while its importance to Union Carbide waned and its morale deteriorated. Though the Madhya Pradesh government's enforcement of pollution and safety standards was timid and haphazard, it was Union Carbide's legal responsibility to ensure safety at its facilities, not the state's. And while it may be true, as one World Bank official put it, that "what is right for Pittsburgh is not right for Calcutta," plants in Pittsburgh are no more immune to failure than their counterparts in Calcutta.[34] As a massive aldicarb oxime leak at Union Carbide's Institute plant demonstrated only nine months after Bhopal, "chemical technology is not necessarily managed more intelligently" in the developed world, pointed out chemist G. Thyagarajan, a researcher at India's Council of Scientific and

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[32] Jasanoff, 1117.

[33] Ember, 65.

[34] Wil Lepkowski, "Chemical Safety in Developing Countries: The Lessons of Bhopal," *Chemical and Engineering News* (April 8, 1985) 9-14.

Industrial Research and head of the Indian team that investigated the MIC leak. "Runaway reactions do not make a distinction between developed and developing countries."[35] Without the information and influence they needed to protect themselves, the citizens of all countries remain vulnerable to catastrophe.

Poisoned Air

Union Carbide officials explain the devastating gas leak of December 2-3, 1984, as an act of sabotage. The company's version of events is roughly as follows: During a change of shifts between 10:45 and 11:15 p.m., a "disgruntled operator" entered the area where three 15,000-gallon, stainless-steel tanks stored refined methyl isocyanate destined for the Sevin production unit. The operator unscrewed a pressure indicator attached to tank E610 and connected a rubber water hose, intending to spoil the batch of 42 metric tons of MIC inside. More than 2000 pounds of water flowed into the tank, where it reacted with MIC to produce methylamine, carbon dioxide, and slowly accumulating heat. The vapor leaked out through a relief valve and through the stack of the vent gas scrubber, a device designed to neutralize poisonous exhausts by spraying them with a caustic soda mixture. Plant operators smelled the escaping MIC vapor and sprayed a fire hose toward what they believed to be its source, an open pipe near the vent gas scrubber. Just after midnight, however, operators saw from control room gauges that pressure was rising rapidly in tank E610. They ran to the tank, allegedly discovered the saboteur's water hose, and decided to try to transfer enough liquid out of the tank to stop the reaction. By then, however, so much heat and pressure had built up inside the tank that a safety valve ruptured and an undetermined amount of MIC vapor wafted out over central Bhopal, where it killed thousands. "Not knowing if the attempted transfer had exacerbated the incident, or whether they could have otherwise prevented it...those involved decided on a cover-up," writes Ashok Kalelkar, an employee of Arthur D. Little, Inc., the Massachusetts consulting-engineering firm hired by Union Carbide to investigate the accident.[36] The operators allegedly altered logs to erase signs that they knew of the water entry and had attempted the MIC transfer.

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[35] Wil Lepkowski, "Bhopal: Indian City Begins to Health but Conflicts Remain," *Chemical and Engineering News* (Dec. 2, 1985) 18-32.

While the sabotage scenario was plausible -- modern chemical plants are highly vulnerable to deliberate mischief -- Union Carbide never offered any direct evidence for it. The company cited a newspaper report that a Sikh extremist group called Black June had claimed responsibility for the accident in a street poster, but the report was uncorroborated and the poster was never found. Investigators based their accusation that operators had altered logs on minor inconsistencies in handwriting and chronology. And if a cover-up did exist, the company had no material evidence as to *what* was being covered up; the conjectured water hose was never located. In his report, Kalelkar attached great importance to the deposition of a "tea boy" whose job it had been to serve tea to operators in the MIC control room. In 1987 Union Carbide agents located the boy in the Nepalese Himalayas and transported him to Delhi, where he said that when he had entered the control room at 12:15 that night, "the atmosphere was tense and quiet" and the operators had refused their tea -- proof, in Kalelkar's view, that a conspiracy was afoot.

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[36] Ashok Kalelkar, "Investigation of Large-Magnitude Incidents: Bhopal as a Case Study," paper prepared for The Institution of Chemical Engineers Conference on Preventing Major Chemical Accidents, London, England, May 1988 (Cambridge, Mass.: Arthur D. Little, Inc., 1988) 26-27.

During litigation, Union Carbide's lawyers repeatedly claimed that they knew the saboteur's identity, but his name has never been released, not even to the Indian authorities.

The biggest flaw in Union Carbide's account of the accident, however, was its fixation on a simple cause: direct, deliberate entry of water into tank E610. In fact, the Bhopal catastrophe was a classic system breakdown of the kind described in Perrow's *Normal Accidents*, which appeared the same year as the disaster. As Perrow wrote in a later article, "the specific way in which the water got into the methyl isocyanate storage tank is not as important as the design and conditions of the plant," since little vapor would have escaped had a series of operating, mechanical, and engineering failures not also occurred.[37] Paul Shrivastava, who is a Bhopal native, a specialist in industrial crisis management, and a Bucknell University professor of management who mediated settlement negotiations between Union Carbide and the Indian government, explains that "accident by sabotage was technologically improbable because the accident had involved *simultaneous* failures in design, technological subsystems, safety devices, managerial decisions, and operating procedures. More importantly, some of these failures occurred several weeks prior to the accident. To intentionally bring about the accident, saboteurs would have had to control operations of virtually the entire plant for several weeks."[38]

A reconstruction of the catastrophe's proximate causes from the best available evidence[39] leaves no doubt that the gas leak had complex human, organizational, and technological origins.[40] But the main reason to reexamine the Bhopal disaster here is not to disprove the sabotage hypothesis or to bolster Perrow's theory of normal accidents. It is, rather, to highlight the crucial links between knowledge, control, and danger which helped persuade U.S. activists and members of Congress of the need to strengthen and codify citizens' protections against technological hazards.

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[37] Charles Perrow, "The Habit of Courting Disaster," *The Nation* (Oct. 11, 1986) cover, 347-356.

[38] Shrivastava, 51. Emphasis in original.

[39] Much of the actual forensic evidence that might help explain the gas leak remains sealed pending ongoing civil and criminal litigation in India.

Bhopal demonstrated that control is meaningless without knowledge. The control Union Carbide thought it exercised over its Indian subsidiary had eroded away through inattention to management problems; the control Bhopal's operators thought they had over the plant proved illusory during the crisis as they stumbled through a series of misjudgments and malfunctions; and the safety the residents of Bhopal's shantytowns thought they enjoyed as neighbors of Union Carbide's "plant medicine" factory, a source of jobs and income in the community, turned out to have been a colossal, if unavoidable, leap of faith. The illusion of absolute control over technology does not *create* danger: the possibility of catastrophic failure is always present, an inherent and ineradicable part of the technological enterprise. But the stronger the illusion of control and the more widely it is shared, the more excluded and vulnerable are industrial technologies' host communities.

Safeguards against chemical leaks began to wither at Bhopal months before the disaster. To prevent interruptions of Sevin production, it was the norm to maintain large supplies of MIC at the plant, a risky practice requiring strict monitoring and careful handling. Procedures at Bhopal were clearly

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[40] Shrivastava combines these three factors into a so-called "HOT" analysis showing "how antecedent conditions for the accident developed and how a complex set of interacting failures led to the disaster." 48-57.

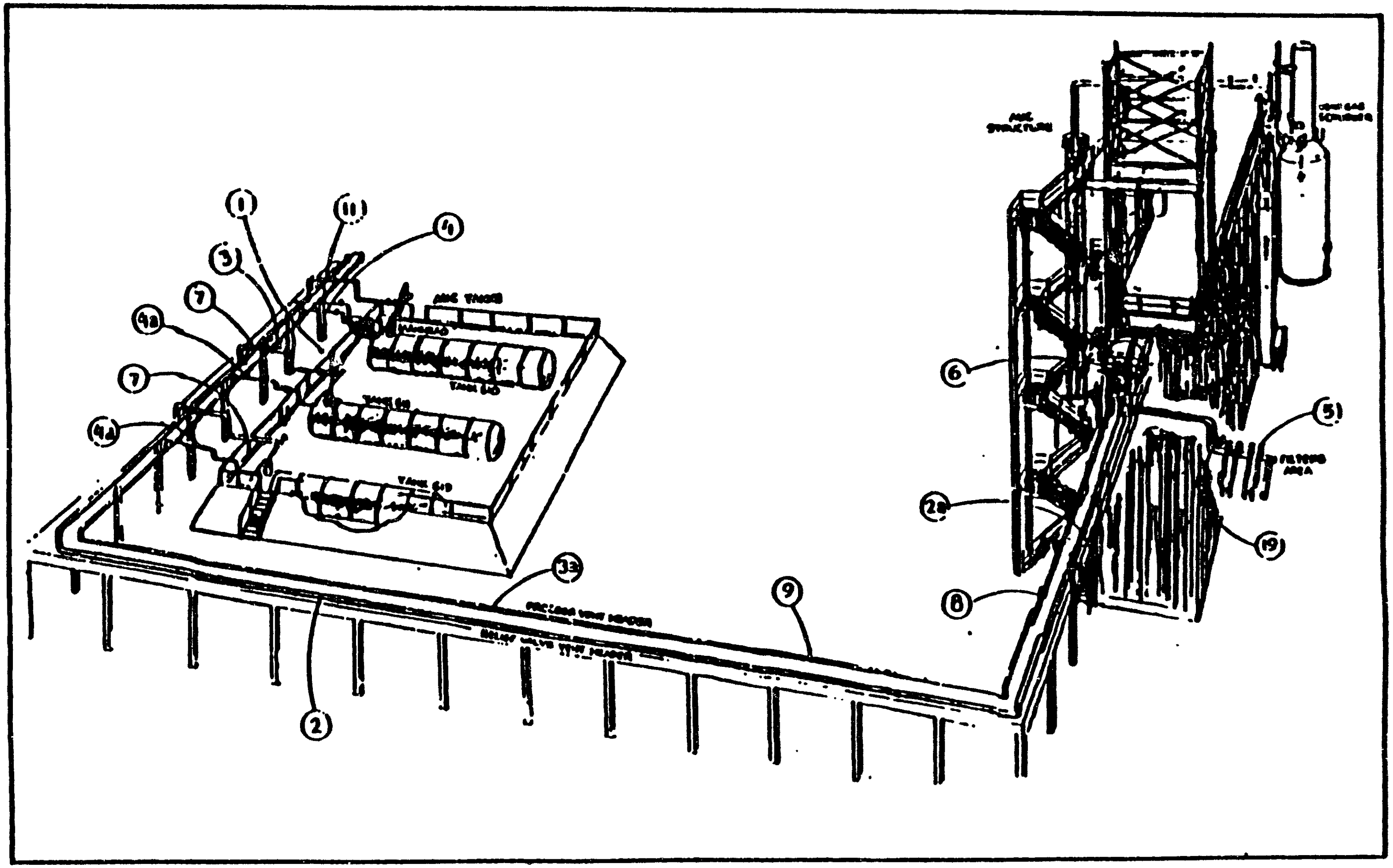
1
11
10
3
7
4a
7
4a
MIC TANKS
33
PROCESS VENT HEADER
RELIEF VALVE VENT HEADER
2
9
8
6
2a
5
19
MIC STRUCTURE
VENT GAS SCRUBBER
FILTERING AREA

Fig. 4.1: Bhopal Methyl Isocyanate Production Facility

Item 6: Production area. Items 2, 3a: Vent Headers. Item 4: Storage Tank Area.

(Source: Ashok S. Kalelkar, _Investigation of Large-Magnitude Incidents: Bhopal as a Case Study_, Arthur D. Little, Inc., 1988, p. 31) unequal to the requirement. When the MIC production area shut down for repairs in October, tank E610 contained 42 tons of MIC, almost 60 percent over its recommended capacity. (See Figure 4.1.) Operators normally used pressurized nitrogen gas to push liquid MIC out of the tanks and into the Sevin production area, but on October 21 nitrogen pressure in tank E610 dropped to one-fifth its normal level and none of the excess MIC could be extracted. To continue Sevin production, managers switched to an adjacent tank, E611, which held 20 tons of MIC. They never investigated the cause of the pressure loss in tank E610. On November 30, nitrogen pressure failed in tank E611 as well, prompting attempts to repressurize tank E610, but operators later told journalists that every time nitrogen was pumped in, it leaked out again through an unknown route. A defective valve attached to tank E611 was repaired and tank E610 was again abandoned.[41]

Without positive pressure in tank E610 over the intervening weeks, meanwhile, the pipes became contaminated by small amounts of water, which reacted with MIC residue to form a clogging plastic substance called trimer. Trimer buildup could only be flushed out with more water. At 9:15 on the night of December 2, Gori Shankar, a second-shift supervisor with only two months' experience at the MIC plant, asked operator Rahaman Khan to flush out several pipes leading to the vent gas scrubber via the storage tanks. While Shankar watched, Khan opened a nozzle on one of the pipes and inserted a water hose. Though there was a closed valve between the nozzle and the storage tanks, operators knew that the plant's valves frequently leaked, and Union Carbide's MIC operating manual required that maintenance workers insert a metal disc called a slip bind inside the pipe before water-washing to prevent any possibility of water entry. But there was no second-shift maintenance supervisor on duty that night -- the position had been eliminated several days before -- and the slip bind was never inserted.

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[41] Details in this and the following seven paragraphs are drawn from Shrivastava, 42-57; Diamond, "The Disaster in Bhopal: Workers Recall Horror"; Diamond, "The Bhopal Disaster: How it Happened"; Worthy, "Methyl Isocyanate: Chemistry of a Hazard"; Lepkowski, "Bhopal: Indian City Begins to Heal But Conflicts Remain."

Khan turned on the water at 9:30 p.m. Unbeknownst to the two men, the overflow lines through which the flushing water should have been draining were plugged. The water backed up and began to rise past the unprotected and apparently leaky valve into the relief-valve pipes, then ran downhill toward the storage tanks. Khan noticed that no water was coming out the overflow line and turned off the hose, but Shankar ordered him to resume the flushing operation. The two then left the area, intending to let the hose run for about three hours. The water overflowed the relief-valve pipes and entered the process pipes via jumper connections between the two systems. From the process pipes, the water flowed through an unsealed valve used to establish nitrogen pressure inside the tank[42] and into tank E610, where it began to react with MIC.[43]

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[42] This valve, the blow-down valve, may have been responsible for the undiscovered leak in the nitrogen pressure system.

[43] Ashok Kalelkar argues on the basis of his Union Carbide-sponsored inspection of the Bhopal facility that "the water-washing theory is clearly untenable...The bleeder valves in the water-washing area would have had to be closed (but three were witnessed to have been open), the intermediate header valves would have had to be open (but one is documented to have been closed and leak tight), and there would have had to be hundreds of pounds of water in the 220-foot section of the process vent header drilled after the incident was over (but not a single drop was found)" (Kalelkar, page 16). Kalelkar does not say who witnessed the open bleeder valves. He assumes from plant maintenance records indicating that the intermediate header valve was closed that it was indeed closed (while at the same time questioning the truthfulness of other records kept by operators). He does not describe the conditions of the simulation that allegedly showed the intermediate header valve to be "leak tight." And he assumes that there was no other possible escape for the water he expected to be found in the process vent header two months after the accident.

Clearly, this is not the forum in which a final verdict on the gas leak's causes will be reached. But for completeness' sake a third theory should be mentioned, one which skirts Kalelkar's objections to the water-washing scenario. According to this theory, favored by

In a cost-saving move five months earlier, plant managers had shut down the refrigeration unit attached to the three MIC storage tanks and siphoned off its freon coolant for use elsewhere, allowing the temperature in the tanks to rise to nearly 20 degrees centigrade -- far above the 5 degree maximum dictated by Union Carbide's technical manual. When the exothermic water-MIC reaction began, therefore, it took little time for the mixture to reach its boiling point of 39 degrees centigrade. The new operators coming on duty at 10:30 p.m. noted and logged the pressure indicated on the control-room gauge for tank E610 -- it was normal, two pounds per square inch -- but they did not record the temperature. "For a very long time we [had] not watched the temperature. There was no column to record it in the log books," said one worker.

At 11:00 p.m. control room operator Suman Dey noticed that pressure in tank E610 had risen to 10 pounds per square inch, an unusually rapid increase but still within the normal range of 2 to 25 pounds per square inch. Shakil Qureshi, who had just replaced Shankar as MIC shift supervisor, later said he thought the pressure gauge was faulty. "Instruments often didn't work," Qureshi explained. "They got corroded. Crystals would form on them." At 11:30, however, workers in the MIC area began to suffer teary eyes, a sure sign

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Indian scientists who conducted their own investigation of the accident, lax maintenance allowed trace amounts of contaminants -- sodium hydroxide, metallic chlorides, rust, or as little as a cupful of water -- to catalyze a runaway reaction of MIC with itself. "In the presence of a catalyst, purified MIC will form either a cyclic trimer (trimethyl isocyanurate) or a grimy, resinous polymer," writes chemist Ward Worthy. The process liberates 540 Btu of heat per pound of MIC. Aware of the dangers of contamination and self-polymerization of MIC, Union Carbide prescribed that the chemical be handled using only steel, glass, or flourocarbon resin containers and tubes. Yet a UCIL production superintendent admitted to journalists that "we just didn't know that MIC could be that reactive." See Worthy, "Methyl Isocyanate: Chemistry of a Hazard," 28, and Lepkowski, "Bhopal: Indian City Begins to Heal But Conflicts Remain," 22.

of a leak. ("We were human leak detectors," Dey said, though this method violated Union Carbide regulations.) They a found a small amount of dirty water and yellowish MIC gas coming out one of the relief-valve pipe heads and notified the control room. Qureshi decided that the leak would be corrected after the nightly 12:15 control room tea break. (This was when the Himalayan tea boy allegedly observed that the control room was "tense and quiet.")

When Dey finished his tea and looked again at the instrument panel, he was astonished to see that both the temperature and pressure gauges for tank E610 had risen past the top of their scales -- 25 degrees centigrade and 55 pounds per square inch, respectively. The control room lacked computerized alarms, like those at its sister plant in Institute, that would have alerted operators to the rising levels sooner. Dey told Qureshi about the pressure increase and ran to the tanks to investigate. He heard the tank's safety valve hissing loudly. (The valve was designed to burst open only if the gas temperature inside the tank exceeded 121 degrees centigrade.) The tank, half-buried in a cement liner, was rumbling and screeching and the cement around it had begun to crack. The local temperature and pressure gauges were off the scale. Above, a white cloud of MIC drifted slowly southeast toward Jaiprakash Nagar.

Dey ran back to the control room and tried to activate the vent gas scrubber. The scrubber had been out of use since MIC production ceased in October, and the caustic soda mixture in the substance failed to circulate. Even if the scrubber had functioned correctly, however, few deaths would have been prevented, since the volume, temperature, and pressure of the escaping gas far exceeded its scrubbing capacity. The plant's flare tower could have burned off some of the gas, but it was missing a section of pipe. The last safety device that might have contained the spreading cloud -- the water spray system on the plant's periphery -- raised a curtain of water only 100 feet high. Most of the gas spewed from a vent pipe 120 feet off the ground. Everyone but Qureshi, six operators, and one administrator fled the plant. Before the remaining staff could devise a response to the leak, MIC vapor engulfed the control room itself. "I couldn't see two feet in front of me, the cloud was so thick. I thought I was going to die," Qureshi said. Unable to locate an emergency oxygen mask, Qureshi ran for a clear area near the plant's six-foot, barbed-wire fence. He scaled the fence, breaking his leg on the descent. Dey, who had oxygen gear, stayed behind to watch the control room gauges until all the MIC in tank E610 had escaped.

Between 12:30 and 3:00 a.m., some 38 metric tons of MIC and reaction products poisoned the air over Bhopal. In the annals of chemical disasters, it was not an especially severe release. In the United States alone, 17 accidents between 1964 and 1989 resulted in the escape of larger volumes of toxic chemicals, but favorable weather conditions, remoteness from population centers, and rapid evacuation efforts held injuries in these incidents to 815 and deaths to only five.[44] Bhopal was not so lucky. The air was cool and dry that night; a light wind was blowing from the northwest at four miles per hour and a temperature inversion like those that plague smog-ridden Denver and Los Angeles straddled the city. The 40-square-kilometer area over which the MIC cloud spread was the most densely populated in Bhopal. UCIL had made token gestures toward an evacuation plan: six buses waited on a lot at the plant's edge, and an emergency siren could be used to warn the surrounding settlements of danger. But five of the buses had flat tires, and there was nobody left to drive the last bus since workers had fled the plant on foot. The siren was not activated until half an hour after the leak began, and inexplicably, operators turned it off only minutes later.

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[44] Philip Shabecoff, "Bhopal Disaster Rivals 17 in U.S.," *The New York Times* (April 30, 1989) 1.

According to the U.S. National Institute for Occupational Safety and Health, the maximum "safe" level of human exposure to MIC vapor is 0.02 parts per million over an 8-hour period -- equivalent to a teaspoonful of MIC in 50 Olympic-size swimming pools full of air. Eye, nose, and throat irritation set in at 2 parts per million and exposure becomes "unbearable" at 21 parts per million. In laboratory studies of rats and mice, exposures of 20 to 30 parts per million over two hours cause death.[45] Scientists disagree about the concentration of MIC in Bhopal immediately after the accident, but simple calculations show that it was worse than unbearable, perhaps as high as 50 parts per million in some locations.[46] The gas attacked people's eyes, raising blinding ulcers on their corneas, and their lungs, causing bronchial spasms and massive secretions of liquid into the alveoli. Thousands suffocated or drowned in their own body fluids. Many died in their sleep, but others were roused by burning eyes, coughing, and the noisy panic and ran out into the streets, where they were finally overcome. The gas killed at least 1,000 people that night and inflicted injuries that would prove fatal for another 2,000 before the week was out.

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[45] Pushpa S. Mehta, et al., "Bhopal Tragedy's Health Effects: A Review of MIC Toxicity," *Journal of the American Medical Association* (Dec. 5, 1990) 2781-87.

[46] The safe concentration of 0.02 parts per million can also be expressed as 0.05 mg of MIC per cubic meter of air. To dilute the 38,000 kg of MIC and other reaction products that escaped from the Bhopal plant to a safe concentration would therefore have required 7.6×10^{11} cubic meters or 760 cubic kilometers of air. But since the gas cloud was mainly confined to an area 40 kilometers square and no more than 50 meters high, with a total volume of 80 cubic kilometers, its *average* concentration must have been at least 9.5 times the safe concentration. Obviously, however, the gas cloud was not evenly distributed over this area. The Union Carbide plant is three kilometers northwest of Bhopal's central railroad station, and over a period of two hours all 38,000 kg of MIC gas had to either settle in a three-kilometer circle around the station or pass through this circle. Average exposure within this circle over two hours would therefore have been at least 540 times the safe level, or 11 parts per million. Assuming that most of the cloud stayed below an altitude of 5 meters rather than 50 (in fact, many of the survivors were those who climbed to the roofs or second floors of their buildings), human exposures could easily have been far beyond the lethal laboratory level of 20-30 parts per million.

At Bhopal's four major hospitals, 300 physicians treated some 90,000 patients in the first 24 hours after the leak. Lacking information about the gas's toxic effects or possible antidotes, they could administer only the most general remedies: eyewashes, furosemide (a diuretic to counteract fluid buildup in the lungs), and a catch-all battery of pills and injections. UCIL officials insisted at first that MIC was nothing more than an eye irritant. Only several days after the disaster did doctors become certain that MIC, and not phosgene or hydrogen cyanide, was the actual culprit.[47] Though Union Carbide scientists in the U.S. had "the best information on MIC toxicity around," according to industry journalists, the company considered the results of its laboratory studies proprietary.[48] Union Carbide dispatched eye and lung specialists to India along with medicines, oxygen, respirators, and $10,000 in cash, but these gestures meant little in the absence of firm information about the toxin. "The truth is that we were unable to communicate to [the medical community in Bhopal] what they needed to know," said UCIL's managing director, V.P. Gokhale.[49]

The confusion of the days and weeks after the disaster made it impossible to assemble an exact death toll. Cremation and mass burials began before all of the dead could be identified, and later estimates of their numbers varied according to the interests of the groups making them.[50] Some of the mortality figures offered were as follows: Union Carbide, 1,000; the Government of India, 1,800; the *Times of India* and *India Today*, 2,500; the International Red Cross, 3,000; the Delhi Science Forum, an independent public-interest group, 5,000; miscellaneous Indian and foreign journalists, 6,000 to 15,000. Mark Wexler, a sociologist, reported that "circumstantial evidence such as number of shrouds sold, cremation wood used during the week after the disaster, and missing persons reports place the figure at 10,000."[51]

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[47] The conclusion of a prominent Bhopal forensic pathologist that gas victims had died from cyanide poisoning, however, led to an extended controversy over whether Union Carbide had concealed the true nature of the gas leak. Activists spent much of their time during the first three months after the disaster lobbying for the release of supplies of thiosulfate, a cyanide antidote -- a "tactical error" that "could have been avoided if they had realized that MIC was as deadly in its own right as cyanide," writes Sheila Jasanoff (p. 1116-17). Clinical and pathological signs of cyanide poisoning can also be produced by MIC and other effects, scientists point out (Mehta et al., p. 2782).

[48] Ron Dagani, "Data on MIC's Toxicity Are Scant, Leave Much To Be Learned," *Chemical and Engineering News* (Feb. 11, 1985) 37-40.

[49] Lepkowski, "Bhopal: Indian City Begins to Heal," 26.

As shocking as these numbers were, the ongoing tragedy of Bhopal is that at least 200,000 gas-affected residents still suffer from debilitating respiratory and ophthalmic illnesses.[52] Scar tissue constricts the lung airways of many of those who inhaled MIC. Like emphysema or tuberculosis, these injuries cause frequent breathlessness, coughing, throat irritation, choking, chest pain, and hemoptysis (coughing up blood). Chronic conjunctivitis, a painful inflammation of the inner lining of the eyelids, affects at least 15 percent of the victims. Among women who were pregnant at the time of exposure, 43 percent suffered spontaneous abortions, four to seven times the usual rate in Bhopal. Many surviving infants had multiple birth defects such as spina bifida, limb deformities, and heart and lung diseases. Menstrual disorders were widespread among women, and physicians also noted a variety of other effects in the population, including immune system suppression, blood diseases, neuromuscular impairment, and psychiatric symptoms. The lack of funding for large-scale epidemiological studies, however, has left the overall health picture in Bhopal scanty and unreliable.[53]

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[50] Just as at Chernobyl sixteen months later; see Chapter 5.

[51] Wexler, 123.

[52] Arvind Rajagopal, "Continuing Tragedy: An International Medical Team in Bhopal," *Frontline* (March 11, 1994) 80-84.

Knowledge, Control, and Danger

The safety of the people of Bhopal depended on control and the way it was distributed, and control, in turn, flowed from knowledge and the way *it* was shared. The substrate for the disaster, the base on which events fed and grew, was a combination of technical flaws in the Bhopal plant's design and construction. Among these were a process design calling for the handling and storage of dangerously large amounts of MIC; corroded and leaking valves; a jumper connection that allowed water from the pipe-flushing operation to flow to the storage tanks; a control room with unreliable dials and gauges and without automatic safety alarms; a vent gas scrubber that did not start when needed and that was underdesigned for actual emergency conditions; and a water spray system that could not reach to the height of the actual leak. None of these pre-existing factors, however, actually *caused* the devastation of December 3, 1984. A full accounting of that night must focus on what was known about these and other conditions, by whom, and how this knowledge (or lack thereof) helped determine people's actions.

Among the facts known to the Bhopal plant's operators were that layoffs had spread the burden of safety and maintenance thinly among a small staff, that tank E610 was overfilled, that water and MIC reacted together violently, that there was a leak in the tank's nitrogen pressurizer system, that the MIC temperature was higher than regulations allowed, that water contamination had caused trimer to build up in the pipes, that a slip bind should have been inserted before washing the pipes, that the water was not draining where it should have been during the flushing operation, that the water curtain was inadequate, that both the flare tower and the vent gas scrubber were out of commission, and that MIC was leaking from the vent tower. The operators *did not* know that the slip bind had not been inserted, that water was actually flowing into tank E610, that the temperature in the tank was rising rapidly after 9:30 p.m., that the pressure gauges in the control room were accurate, that the vent gas scrubber was difficult to start, that MIC vapor was more than an eye and skin irritant, that there were not enough oxygen masks to go around, or that a runaway reaction was occurring in tank E610 while they were on their tea break.

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[53] Mehta et al., 2783-85.

Of the known deficiencies at the plant, most stemmed from management decisions beyond the operators' realm. Everything else the operators knew -- all the information they might have acted upon to prevent the disaster -- was canceled out, in effect, by what they did not know. Most fundamentally, they did not understand MIC's reactivity and toxicity, because they had never been fully informed about it. It is unimaginable that the operators would have acted so carelessly had they appreciated MIC's unstable chemistry. At the Union Carbide plant "there [was] a high degree of secretiveness even in matters of safety," said D. Lakshminarayana, a former Deputy Chief Inspector of Factories in Madhya Pradesh. "So absolutely rigid is Union Carbide's monopoly on information on this gas, that its employees...are never ever permitted, not even during their training, to take the company's specialized literature and safety manuals outside its premises.

Notes can be taken down only with the sanction of the manager."[54] Because the operators did not comprehend the plant's hazards, they were not in a position to protect themselves or the public against those hazards. It cannot be said that they "lost control" of the plant. They never had much to begin with.

If not the technology and not the operators, then who or what was responsible for the catastrophe? Union Carbide's legal and financial liability as the majority owner of UCIL was never seriously disputed, though the company used the sabotage theory as an argument to try to reduce that liability. As the only involved party with the real power to prevent the disaster, the company must bear much of the final blame. Yet the multinational corporation's contribution to the actual events of that night was curiously passive. Officials at Union Carbide's U.S. headquarters knew that MIC was a dangerous toxin, that there were safer ways to make carbaryl, that the Sevin facility could have been designed with much smaller MIC storage needs, that the Bhopal unit was plagued by management and technical problems, and that the plant's safety systems were inadequate.[55] But the company acknowledged later that "no direct authority link" was in place between headquarters and UCIL. It was simply assumed that the subsidiary would correct the problems noted in the 1982 safety audit. After the disaster, Union Carbide officials said they were not aware that operating conditions at the plant had deteriorated so badly. Chairman Warren Anderson admitted to reporters in 1985 that "appropriate people in the organization should have known" about the state of the plant, and said that had he known himself, he would have shut it down.[56]

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[54] Lakshminarayana added that "the most serious lacuna in the safety policy of many of these hazardous factories...is the absence of a manual of safety standards made available to all employees at all levels." Interview reprinted from *Indian Express* in Eklavya's pamphlet *Bhopal: A People's View of Death, and Their Right to Know and Live* (1986), p. 52.

[55] Edward Munoz, a retired Union Carbide vice president and managing director of UCIL at the time of the MIC plant's construction, stated in an affidavit that Union Carbide officials had overruled UCIL's preference for smaller, safer MIC storage facilities. Ward Morehouse and M. Arun Subramaniam, *The Bhopal Tragedy: What Really Happened and What It Means for American Workers and Communities At Risk* (New York: Council on International and Public Affairs, 1986) 3.

The Bhopal unit's unprofitability may explain much of Union Carbide's inattention. Industry analysts also suggested, however, that Union Carbide's oversight of the plant had been hampered by the Indian indigenization policy calling for the use of local materials, labor, and expertise during construction and operation. "If developing countries continue to insist on a dilution of multinational corporate control," wrote two contributors to the *Wall Street Journal*'s opinion page, "they will also be diminishing the motivation and capacity of companies to invest and to transfer environmental management and safety competence."[57] But this argument, like the one about the impossibility of transferring a safety ethic to developing nations, fails to diminish Union Carbide's responsibility. Indian law required the company to use Indian labor, materials, and staff *only when* the needed resources were available locally. If the plant's safety could not be guaranteed using local equipment and personnel, then the company was free to import them from elsewhere.

The choices Union Carbide made were, finally, inexplicable: It neither brought in qualified outsiders nor verified that local workers were adequately trained. It failed to determine whether known safety problems at the plant were being corrected. It withheld study results warning of the possibility of a runaway reaction in the MIC storage tank. And it failed to share adequate information on MIC's toxic properties even after thousands had died. The list of ways in which Union Carbide helped cause the Bhopal catastrophe is, in other words, a list of things company officials *chose not to know* together with things they *chose not to do*. In both cases, curbs on knowledge resulted in the forfeit of control.

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[56] Wil Lepkowski, "Bhopal Disaster: Union Carbide Explains Gas Leak," *Chemical and Engineering News* (March 25, 1985) 4-5.

[57] Thomas M. Gladwin and Ingo Walter, "Bhopal and the Multinational," *The Wall Street Journal* (Jan. 16, 1985) 28.

The people who paid the largest price for the disaster, the gas victims themselves, knew less about the plant's true dangers than anyone. Some said Bhopal's shanty-dwellers had known all they needed to know: that the Union Carbide plant represented jobs, prosperity, and modernity. "Of those people killed, half would not have been alive today if it weren't for that plant and the modern health standards made possible by the wide use of pesticides," said Melvin Kranzberg, a pioneer U.S. historian of technology. "We accept the benefits that technology brings us until there's an accident or catastrophe, and *then* we begin to worry," Kranzberg added.[58] From this point of view, the accident was merely part of the "pain of progress": the people of Bhopal were getting what they bargained for. But this attitude's smugness was matched only by its naiveté. Many of those killed and injured in the gas disaster had come to Bhopal precisely to escape the rural economic disruption brought on by the Green Revolution and its heavy reliance on pesticides. Moreover, the city's residents had no access to information about the plant's dangers or about how they might protect themselves in the event of a chemical emergency. Union Carbide's decision to exclude the public from all forms of knowledge about plant hazards effectively blocked external control and guaranteed a tremendous death toll when internal control itself shattered.

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[58] William J. Broad, "Risks and Benefits: Disaster in India Spreads Net of Fear and Raises Issues of Technology's Cost," *The New York Times* (Dec. 7, 1984) A12. Emphasis added.

It is fair to ask however, how knowledge alone could have protected the people of Bhopal against danger. Individual residents of Jaiprakash Nagar and the other shantytowns, had they learned before 1984 of the toxicity of methyl isocyanate, the inadequacy of the plant's control systems, or the sorry state of emergency preparations, would still have lacked the political and economic power to win safety improvements; and in any case, the most critical safety-related decisions (those having to do with the location of the plant and whether MIC would be manufactured there) had been made a decade earlier. But had information about the plant's hazards been shared, it might at least have forced a recognition of the need for organized attempts to gain power. Without this information, no one in Bhopal could perceive the shadow of risk that had settled over the city, and it would take the gas tragedy itself to goad the people into organizing in their own defense: an outcome that, as much as anything else, epitomizes the argument of this thesis.

Indian Citizens Respond

As headlines and television pictures carried the stunning reality of the gas disaster around the world, volunteers assembled a massive effort to help the survivors. Thousands of private citizens poured into Bhopal ahead of the army and police brigades, helping to remove the dead, provide food and clothing for the dispossessed, and build refugee camps. Students, trade unions, and other groups around Madhya Pradesh collected relief funds. Rickshaw drivers transported the sick to hospitals free of charge. "With elections around the corner, candidates and political parties mobilized their workers for relief work, publicizing their contribution in the process," reported the local *Madhya Pradesh Chronicle.*[59] The need for medical relief and material assistance promised to continue for years, however, and some volunteers decided that another kind of response to the disaster was also necessary: grassroots action to eliminate the conditions that had brought about the catastrophe.

Citizen organizing is an honored tradition in India, with roots in Mohandas Gandhi's non-violent activism for Indian independence, pure democracy, social equality, and artisanal village-based production. The public interest groups webbing the country play an important mediating role between India's population and its massive and sluggish government bureaucracy. From the first days of independence, however, the Gandhian program for small-scale economics conflicted with Prime Minister Jawaharlal Nehru's vision of material plenty through rapid industrialization. Debate about technology's proper role in social progress became one of the earliest themes in contests over government policy. Disillusioned during the nineteen-sixties and seventies by the persistence of caste differences and the unintended consequences of the Green Revolution, many young state-educated scientific and technical professionals discarded the idea that the state could direct science and technology for the social welfare and formed their own alternative network of "public science" activist groups. One such group, the Delhi Science Forum, states that its goals are "to stimulate informed public debate on the precise way in which science and technology interact with our society" and "to create awareness and to articulate problems related to the environment in which scientists and technologists are working in our country today."[60] Members of this movement viewed the Bhopal disaster as an indictment of Nehruvian policies and Indian dependence on imported technology, and they quickly flocked to the stricken city to help organize the victims in a call for reform.

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[59] Eklavya, *Bhopal: A People's View of Death, and Their Right to Know and Live,* 15.

[60] From *Bhopal Gas Tragedy: Delhi Science Forum Report* (New Delhi: Society for Delhi

The Zahreeli Gas Kand Sangharsh Morcha, or Poison Gas Struggle Front, formed within days after the disaster to coordinate protest actions. "Local people worked alongside professionals, academics, trade unionists and others in a mammoth effort to respond to the urgency of the situation," writes Laughlin. "In so doing, however, the Morcha did not simply prioritize relief and relegate critical perspectives to secondary importance...The Morcha took a very critical stand on Bhopal as an issue in the ongoing debate about the role of technology in the development of Indian society. The Morcha represented the disaster as the outcome of economic planning which prioritized high-speed growth...Perhaps most significantly, they questioned the ability of technology to solve problems of its own creation."[61] The group spotlighted inefficient government relief programs and state and municipal officials' failure to crack down on Union Carbide's safety violations. Its insistence on public access to epidemiological data and to official reports on the disaster was new and radical in India, where secrecy in government was the norm. (As Madhya Pradesh minister Arjun Singh had explained to reporters, "Information will spread fear."[62])

Fearing, in fact, that government investigators might suppress all information about the disaster's true causes out of reluctance to antagonize foreign investors, the Delhi Science Forum sent its own team of experts to

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Science Forum, 1984) 49.

[61] Laughlin, "Rehabilitating Science, Imagining Bhopal," 17.

[62] "Bhopal Update: India, U.S. Still Grapple with Effects," *Chemical and Engineering News* (Jan. 21, 1985) 4-6.

Bhopal. Their first report, released only weeks after the accident, focused on MIC's toxicity and the design and management decisions that had rendered the UCIL plant less safe than its West Virginia prototype. The Forum investigators said they had discovered evidence of gross negligence on the part of Union Carbide and UCIL, including "astonishingly deficient" maintenance and safety systems that were "utterly underdesigned." Yet the report's authors saved their roughest criticism for the Indian government, charging that there had been a "total absence of measures to educate the public as well as medical personnel, which would have greatly ameliorated the condition of the affected population." The Forum scientists called for a "fully informative" government assessment of the tragedy "with details which could be cross-checked independently." A broad coalition of Indian professionals and workers should work together to overcome government apathy toward industrial safety, the report recommended: "It is only the vigilance of the people at large, and the scientific community in particular, which can guarantee safe harnessing of science and technology for human welfare."[63]

Among the voluntary groups that adopted Bhopal as a symbol of the need for wider public involvement in technological decision-making was Eklavya, founded in 1982 to enhance science education in Madhya Pradesh. Recounted Vinod Raina, a theoretical physicist who led Eklavya, "When the leak happened, we did the type of volunteer work everyone else was doing. Then we thought a bit and decided our main task should be in information. This was an example of a science-society catastrophe where the uninformed were victims of a vicious manifestation of ignorance. So we decided to play a significant role in simplifying matters and tell people whatever we were able to find out through our own investigations...There were so many Indian groups writing to us for information that we decided to write our own report on the tragedy at a time of much conflicting information. Officials would be saying on the one hand that the water was safe, but to boil it before drinking it. They were saying the vegetables were okay, but wash them." Eklavya commissioned independent scientists to monitor Bhopal's fields, gardens, and water supplies for MIC breakdown products and soon published a "people's report" on public health concerns in the city. (Environmentalists and anti-nuclear groups in Ukraine would take up similar tactics after the Chernobyl explosion, as will be described in the next chapter.)

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[63] *Bhopal Gas Tragedy: Delhi Science Forum Report* , 2, 36-40.

While such efforts offered an active counterexample to the government's tight-lipped treatment of the disaster, however, the public science movement's ultimate accomplishments in Bhopal were limited by several inescapable realities. Foremost was the victims' extreme disenfranchisement within Indian society. They were "wretchedly poor people with no history of social organization and certainly no significant political experience," Indian journalist Praful Bidwai observed. "Naturally, in the debates of the state assembly, they count for nothing. In Parliament, too, they have at best attracted desultory attention. In Bhopal itself, the middle class does not think of them...Voluntary groups, professional relief organizations and charities have by and large ignored them. Even environmentalists and safety activists, both part of a growing movement in India, have not taken up Bhopal as their principal cause but only as one among many."[64] Volunteers could help the victims organize, but they could not hope to provide them with political power or with more than a fraction of the medical and financial resources they needed. Once the Indian government decided in 1985 to sue Union Carbide on behalf of all the victims, nullifying independent legal actions, real compensation became a matter for the two sides' attorneys to decide, and there was little the victims could do but wait. (In 1986 the government agreed to pay a meager $766 in interim relief to the families of each of those who died and $115 to the families of those injured. By 1993 it had only just begun the slow process of distributing the $470 million Union Carbide paid in the 1989 settlement.)

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[64] Praful Bidwai, "Bhopal," *The Times Of India* (Dec. 3, 1986), reprinted in *World Press Review* (March, 1987) 56.

Class differences between the victims and their would-be organizers, meanwhile, could not help but influence their work together. In contrast to those who lived in the shantytowns, the professionals leading the public science movement were highly educated, often more so than the government officials they criticized. At the core of groups like Eklavya or the Bhopal Group for Information and Action there was usually only a handful of itinerant activists. The awkwardness of their position was self-evident. "An extraordinary number of activists in the Indian Left are trained as scientists, engineers or medical doctors," noted Laughlin. "Yet, a primary critique is of the role science and technology has played in the development of Indian society. This obliges [them] to continually ask if there is any possibility of an 'appropriate technology of expertise.'"[65] Activists were wary of framing the gas victims' concerns *for* them -- of perpetuating the old patterns of dependence on outsiders -- yet the organizations staffed by the university elites always ended up being led by outsiders. This dilemma, and the discouraging vastness of the problem itself, drove many volunteers out of

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[65] Laughlin, 18.

Bhopal. As one activist explained, the movement "gradually tapered down to a dismal state due to a combination of lack of effort, autocracy within the organizations, hopelessness among the people due to lack of any history of organized struggle, and of course the state's repression."[66]

The largest and most effective example of grassroots cooperation in Bhopal was a group organized by the victims themselves, the Gas Peedit Mahila Udyog Sangathan (Gas-Affected Working Women's Union). The Sangathan formed at a sewing center employing women who had gas-related illnesses or whose husbands had died or been incapacitated in the disaster. Thirty women cut cloth at the center and distributed it to another 600 for sewing in their homes. The work paid $7 per month on average and was one of the few sources of cash in the community. When the government shut down the sewing center in 1986, the cloth cutters mobilized hundreds of seamstresses to march on the residence of the Chief Minister of Madhya Pradesh in a confrontation that continued for months. "We had to face the police on many occasions," recounted one of the protest organizers, a woman named Mohini. "In April, 1987, 225 of us were arrested and put in jail. It was a long and hard struggle. Most of us were quite sick due to the gas. During one demonstration a women named Hamida Bi fell unconscious with chest pain and died four days later."[67] The Sangathan eventually managed to get the sewing center reopened on a much larger scale, employing 2,300 women.

Though budget cuts closed the center again in 1993 to renewed protest, the Sangathan's membership had grown by then to 14,000 women and the group had taken on a range of victims' causes, including tracking the legal case against Union Carbide, providing health care information and job counseling, and assisting Bhopal residents in their dealings with the Indian relief bureaucracy.[68] "The primary fight of the Sangathan has been for restoration of local control through extended participation of community members," writes Laughlin. In 1988 the group helped to secure interim relief payments of 200 rupees ($5) per month for the victims. In 1991 the Sangathan called for the creation of a new medical commission to reassess the number of permanently injured gas victims (a number far larger than the court's estimate of 30,000, the union asserted) and petitioned India's Supreme Court to overturn the $470 million settlement in favor of a renewed $3.3 billion liability suit against Union Carbide.[69] "Among gas victims, faith in the legal process is not strong," explained a pamphlet published by the Bhopal Group for Information and Action, "[but] victims forcefully argue that they would have been ignored completely had they not carried out sustained public protest."[70]

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[66] Quoted in Tara Jones, *Corporate Killing: Bhopals Will Happen* (London: Free Association Books, 1988) 73-78.

[67] Bhopal Group for Information and Action, *Voices from Bhopal* , 9-10.

Beyond Bhopal, years of legal jockeying over Union Carbide's liability for the disaster overshadowed news of the gas victims' struggle. Though the company stated in January, 1985, that it hoped to reach a "compassionate and reasonable" settlement within six months, the case has since dragged on for nearly a decade, following a labyrinthine route through both the Indian and U.S. courts.[71] Compensation payments from the $470 million settlement began in 1992, but the government's criminal case against Union Carbide continues. The Indian parliament, meanwhile, emulated environmental legislation in the United States and other industrialized nations in enacting a new Environment Protection Act. The act created a central environmental agency with authority to mandate pollution controls and strengthened regulations on industrial zoning, safety inspections, and emergency planning. Lawmakers also added a new chapter to the Indian Factories Act requiring that all plant hazards, accidents and injuries, and emergency plans be disclosed to authorities.

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[68] Laughlin, 9-10.

[69] David Bergman, "Judges May Free India to Renew Battle over Bhopal," *New Scientist* (Jan. 12, 1991) 24.

[70] *Voices from Bhopal* , 2.

[71] Barry Meier, "Union Carbide Hopes to Settle Claims from Bhopal Acccident Within 6 Months," *The Wall Street Journal* (Jan. 11, 1985) 2; "Carbide Afte Bhopal: Board Chairman Reveals Strategy," *Chemical and Engineering News* (Jan. 14, 1985) 6-7. The Indian government turned down Union Carbide's first settlement offer of $200 million in 1985 and filed suit in U.S. federal district court, asking both compensatory and punitive damages. The company's lawyers requested dismissal, arguing that the claims should be heard in India --

But journalists and environmentalists in India have labeled these measures "halfhearted" and "unsatisfactory," and legal scholars here agree that "it remains to be seen how these new statutes will be implemented...What is required is not necessarily more government

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where, it so happens, the courts do not award punitive damages. Federal Judge John F. Keenan ruled in the company's favor in May, 1986, but ordered Union Carbide to follow stronger U.S. standards of legal discovery in providing information to Indian prosecutors. Carbide appealed the order, asking that it be granted the same evidence-gathering privileges. The U.S. Appeals Court granted the request. At the same time the company filed a countersuit in India claiming that the government had failed to investigate its allegations of sabotage -- a move, legal experts said, signaling that the company had the means to extend the case interminably if India continued to balk at a settlement. Two near-agreements on a $492 million settlement package fell apart in 1987. With sentiment in India divided between reaching a settlement and forcing an actual trial, presiding judge M. W. Deo ordered Union Carbide in December, 1987, to pay $270 million in interim relief. The company refused, and the order was eventually overturned on appeal. In the meantime, Union Carbide attorneys announced that they were "fed up" with the Indian legal system and tried to have the case transferred back to state courts in Connecticut, and a U.S. public interest group filed suit against the company in Texas on behalf of 40,000 Bhopal victims. A 1989 agreement on a settlement payment of $470 million, or about $6,000 per victim, promised to bring the long dispute to an end, but massive public protest and pressure from a newly-elected government forced the Indian Supreme Court to review the figure. When a judgment still had not been delivered two years later, 2,000 survivors of the disaster marched through Bhopal, shouting "No to settlement" and burning effigies of Union Carbide officials. Late in 1991 the court upheld the $470 million settlement but reopened the criminal case against the company. The Indian Central Bureau of Investigation indicted former Union Carbide chairman Warren Anderson and eight UCIL managers. When Anderson failed to comply with India's attempt at extradition, a judge seized all Union Carbide assets and dividends in India.

authority, but more real *power* to ensure that the promises of law do not remain empty."[72] India has pressed on with its industrialization campaign, and the international transfer of hazardous technologies will continue to be one effect of this policy. "Given the limits of state intervention, we must ask if there is a different way of organizing society," insisted Praful Bidwai at a 1991 Delhi conference on Bhopal's aftermath. "There is an accepted notion that certain processes are excessively toxic in relation to conceivable benefits. We must extend the logic: Nuclear power as a means of electrity. Cyanide as a means of electroplating. Sevin, Temik as pesticides....We must disallow Capital's domination of social considerations."[73]

A recent clash between local citizens and the Du Pont Company in the southwestern Indian state of Goa suggests how dramatically the Bhopal disaster has already changed popular Indian attitudes toward multinational business. Du Pont joined with the Indian firm Thapars in 1985 to build a plant in the city of Ponda for the manufacture of Nylon 6,6, a synthetic cord used in radial tires.[74] Eager development officials in Ponda prepared a hilltop site for the factory and agreed to provide cut-rate electricity and water, but local residents were not so welcoming. With a tiny office, no telephone, and virtually no budget, the Anti-Nylon 6,6 Citizens Action Committee roused a collection of farmers, craftsmen, students, and professionals to canvas the region with information on Du Pont's U.S. operations. They distributed data compiled by the New Jersey Health Department describing hexamethylene diamine, a component of Nylon 6,6, as a "hazardous" and "corrosive" substance. The U.S. Coast Guard's Hazardous Materials List, they pointed out, identified 17 chemicals used in Nylon 6,6 as carcinogens. The group also publicized Du Pont's extensive violations of U.S. environmental laws. Asked one activist, "How can we expect that there will not be even worse violations in India, where we still have almost no government oversight?"

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[72] Bidwai, 56; Jamie Cassels, *The Uncertain Promise of Law: Lessons from Bhopal* (Toronto: University of Toronto Press, 1993) 270-72. Emphasis in original.

[73] From the National Convention on Bhopal Gas Leak Disaster and its Aftermath, April 8-9, 1991; reported by Laughlin, 18.

[74] Mark Schapiro, "Du Pont's Post-Bhopal Blues," *The Nation* (Nov. 2, 1992) 499-501.

After enraged residents stormed the Du Pont construction site in 1990 and damaged several buildings, Goa authorities launched a study of the plant's environmental and economic impact. Another raid, the election of a new legislature opposed to the project in 1991, and, in one Du Pont managers's words, "a number of concerns about liability post-Bhopal" put construction on hold for three years while the company developed "a new generation of technology."[75] For citizens tired of the government concessions and unquestioning trust that had always accompanied the transfer of hazardous First World technologies to India, winning the delay against Du Pont was a first.

These isolated uprisings, however, have not made India a drastically different place after Bhopal. Citizens still have little legal power to force the public disclosure of industrial hazards. The agencies administering the new environmental laws are said to be returning to their secretive, exclusionary ways. And in Bhopal itself, life remains nightmarish. The majority of the victims still live in cardboard-and-tarpaulin shacks, and fiery riots after the Hindu demolition of a Muslim mosque in northern India in 1992 killed 150 in Bhopal and destroyed the homes and compensation documents of some 1,300 gas victims.[76] "These were working people, self-sufficient, people who seldom had to consume medicine on a regular basis," writes Arvind Rajagopal, an Indian journalist. "Now they are reduced to a condition akin to beggary, with aches and afflictions and uncontrollable moods that respond to nothing, unable to do much work. For any kind of relief, they have to confront a bureaucracy rendered immune to all human suffering, and often dismissive of their complaints as the mouthings of a lazy population greedy for compensation. Their sense of helplessness is acute. Imagine hundreds of thousands of people in this condition, and you will have some idea of the ongoing disaster in Bhopal."[77]

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[75] Du Pont announced in May, 1994, that construction would resume at the Ponda site. Mary Zane, business strategy manager for Du Pont Nylon Industries in Delaware, said in an interview that the delay had been due to "a number of concerns about liability post-Bhopal" and "a slowdown in our interest based on a determination of what the profitability of the site was and the need to get a better understanding of what the general economic trends were going to be." Zane contended that much of the local opposition to the plant had come from competing factory owners rather than environmentalists. This opposition dried up, she said, after the Indian government forced a local accommodation with Du Pont. "The competition realized that the government was not going to oppose us any more, that they needed to be more embracing of foreign investment if they wanted to get funds from the IMF. They [the government] are trying to be our buddies." Zane promised that Du Pont would be "going in there with all the environmental controls. We would be operating there just as we would operate in Houston, Texas, or in the middle of New York City...We will do the normal thing for going into Asia. We will put in a clinic, a dormitory, schools, a full campus." Zane added, somewhat contradictorily, "It's far more than we would do in the United States." (From the author's notes on a telephone interview with Zane from her office in Delaware, April 27, 1994.)

"It Can Happen Here"

After the catastrophe in India, people living near chemical plants in the United States no longer needed to use their imaginations. Toxic clouds from chemical plant malfunctions or railroad accidents were not an unfamiliar hazard in North America; as recently as as 1979, the derailment of a freight train carrying hazardous materials in Mississauga, Ontario, had forced 250,000 people in a 50-square-kilometer area to leave their homes for up to a week, and in 1980 a 6,000-gallon spill of phosphorous trichloride in densely populated Somerville, Massachusetts, had injured 418 people and forced the evacuation of 23,000.[78] But the images from Bhopal conveyed destruction and defenselessness on a scale few had contemplated before. The fact that U.S. technology had caused this carnage evoked a mixture of guilt, fear, and anger. Just as Three Mile Island had swept away much of the U.S. nuclear industry's credibility, Bhopal left Americans predisposed to doubt chemical makers' reassurances about plant safety.[79]

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[76] Sanjoy Hazarika, "Settlement Slow in India Gas Disaster Claims," *The New York Times* (March 25, 1993) A6.

[77] Rajagopal, 82.

For residents of Institute, West Virginia, events in the Indian city ten-and-a-half time zones away hit especially close to home. The Union Carbide plant in Institute is one of five major chemical factories on the 35-mile-stretch of the Kanawha River known to locals as "Chemical Valley." The town is home to the prototype for the Bhopal MIC facility, as residents were reminded when dozens of journalists arrived the day after the catastrophe. Even among those who had warned of chemical hazards in the valley for years, the extent of the disaster in Bhopal came as a surprise. "What happened in India was far beyond our worst-case scenario. But the identical thing could happen here," said Perry Bryant of the West Virginia Citizens Action Group, a local industry watchdog organization.[80] West Virginia State College student Kaye Summers reflected, "This incident in India kind of brings it home, doesn't it? Here in the valley we are producing something that can kill a thousand people, and I can see this plant from my classroom window. It's scary."[81] Many who had already been nervous about chemical emissions in the valley now began to feel trapped. "There is just one way to go" to escape, said Warne Ferguson, an Institute resident and an administrator at West Virginia State. "You'd have to go east, down that road [Route 25]. West would be toward the source. They tell you to go crosswind, but south is the Kanawha River and north means climbing that mountain. You'd have just one big traffic jam. I'm going to move. I can't justify raising my daughter here."[82] A *Charleston Gazette* survey of Kanawha County residents found that 62 percent believed a catastrophe on the scale of Bhopal could happen in their valley.[83]

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[78] Susan L. Cutter, "Airborne Toxic Releases: Are Communities Prepared?" *Environment* (July/Aug., 1987) 12-17, 28-31.

[79] In a Business Week/Harris poll weeks after the Bhopal disaster, 44 percent of those surveyed said they believed Union Carbide was withholding information about the accident's causes, as against 36 percent who believed the company had told the truth and 28 percent who were unsure. Jones, 32.

[80] Walter V. Robinson, "Worries on Hazardous Gases Waft Over West Virginia's 'Chemical Valley'," *The Boston Globe* (Dec. 7, 1984) 1, 14.

Industry officials dismissed such fears. Though Union Carbide immediately shut down MIC production at Institute to await evidence of the causes of the Bhopal leak, the company insisted that "the West Virginia plant is 'very safe'" and that "residents haven't any cause for concern," the *Wall Street Journal* reported.[84] "The probability of the kind of accident that happened in India happening here is just not the same," said John Holtzman, a spokesman for the Chemical Manufacturers Association.[85] "No, sir. I'm not a bit worried. Our safety precautions are second to none," said Earl Dye, director of security at the Institute MIC plant.[86] Jackson Browning, Union Carbide's vice president for health, safety, and environmental affairs, announced in March, 1985, that "based on comprehensive analysis of what happened in the tank in India, we can confidently say that it can't happen here."[87] Charleston mayor James E. Roark was less sanguine about the dangers of living in the Kanawha Valley, but also less evasive about the real issues at stake. "It's the ultimate question of the Industrial Revolution," he said. "You have to take reasonable risks to achieve reasonable profits."[88]

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[81] Stuart Diamond, "Jobs and Risks are Linked in a U.S. Chemical Valley," *The New York Times* (Dec. 5, 1984) 1, 12.

[82] William Robbins, "Near West Virginia Plant, The Talk is of Escape," *The New York Times* (Dec. 9, 1984) 22.

[83] Jane Slaughter, "Valley of the Shadow of Death," *The Progressive* (March, 1985) 50.

[84] Carol Hymowitz and Terence Roth, "In West Virginia's 'Chemical Valley,' India's Toxic Gas Disaster Stirs Fears," *The Wall Street Journal* (Dec. 5, 1985) 4.

[85] Cathy Trost and Carol Hymowitz, "Congressmen, Environmentalists Fear That Laws In U.S. Wouldn't Prevent a Poison-Gas Disaster," *The Wall Street Journal* (Dec. 6, 1984) 6.

[86] Robinson, 14.

After August 11, 1985, however, "The chemical industry suddenly seemed a lot more risky," as one *New York Times* writer put it.[89] As if to mock the industry's assurances, a series of equipment breakdowns and operator oversights at Union Carbide's Institute plant triggered the eruption of two tons of toxic chemicals into the air over the Kanawha Valley. The events leading up to the release so resembled those in India that the episode drew global media attention and instantly nullified Union Carbide's efforts to rebuild its reputation after Bhopal.

On August 1, operators were mixing methylene chloride and aldicarb oxime in a large tank to make Union Carbide's Temik pesticide. A malfunctioning flow meter allowed too much aldicarb into the tank, and operators transferred the imbalanced solution to another 5,000-gallon, glass-lined tank to await later processing. This second tank had not been used since the previous November, and unbeknownst to operators, steam was flowing through leaky valves into the tank's heating jacket, slowly raising the solution's temperature. A computer monitoring the temperature was not programmed to display this information to operators. As the temperature passed 40 degrees centigrade, the methylene chloride began to boil off and escape into connected vessels, raising the concentration of aldicarb oxime in the tank from 38 percent on August 1 to 81 percent by August 7.

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[87] "Bhopal Disaster: Union Carbide Explains Gas Leak," *Chemical and Engineering News* (March 25, 1985) 5.

[88] Terence Roth, "Carbide T-Shirts and Gas-Leak Worries Clash Near Methyl Isocyanate Facility," *The Wall Street Journal* (April 12, 1985) 12.

[89] Stuart Diamond, "Credibility a Casualty in West Virginia," *The New York Times* (Aug. 18, 1985) E1.

Unaware of this change, operators activated a pump to empty the tank's contents back into the aldicarb reactor, but 500 gallons of the solution formed a hard-to-remove "heel" in the bottom of the convex vessel and remained there. Operators could not tell whether the tank was empty because its volume meter was broken. Over the next four days, leaking steam continued to heat the remaining solution. On Sunday morning, August 11, the reactor temperature reached 149 degrees centigrade, touching off an exothermic decomposition reaction. Safety valves burst under the high pressure and an opaque white cloud began to spew from the plant's flare tower.[90]

Events over the next few minutes gravely tarnished the idea that computerized decision aids could help control-room operators act quickly to protect the public in a chemical emergency. In May, Union Carbide had restarted methyl isocyanate production at Institute after a five-month hiatus. The company boasted that it had spent $5 million installing new safety equipment at Institute, including a computerized vapor emission modeling system that would "instantly alert both the company and the surrounding communities to a leak."[91] Developed by Safer Emergency Systems of California, the system combined information from a network of chemical sensors and weather stations with a three-dimensional model of the plant and the surrounding terrain to produce a full-color graphic display of the expected path of an airborne chemical release. Using this information, operators could quickly notify authorities which areas of the city to evacuate. But when plant alarms sounded at Institute on August 11, operators found that the Safer system contained no information about the chemical properties of aldicarb oxime. They selected a chemical they thought was close -- MIC, as it happened -- and the computer generated a map indicating that the toxic cloud would not drift past the plant's property line.[92] Thus reassured, the operators waited 19 minutes before warning authorities about the release.

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[90] "Carbide Restructures: Problems Prompt Massive Cutback," *Chemical and Engineering News* (Sep. 2, 1985) 6-7;Rick Wartzmann, Barry Meier, and Thomas Petzinger, "Union Carbide Cites Errors in Chemical Leak; Company Stumbles in Delivering on Its Safety Promises," *The Wall Street Journal* (Aug. 26, 1985) 6.

[91] United Press International, "Union Carbide Plant to Restart In West Virginia," *The New York Times* (May 3, 1985) A12.

By that time, however, the cloud had already engulfed a nearby golf course and a residential neighborhood, sending 135 people to hospitals with eye, throat, and lung irritation. (Fortunately, aldicarb oxime is only one-tenth as toxic as MIC.) The cloud also entered the control room itself, making it "virtually impossible for operators to see the control board or see the doors for escape," according to the head of the company's investigation.[93] This complication contributed to the 19-minute delay, but the Environmental Protection Agency concluded later that "Union Carbide staff outside the release area...should have contacted Kanawha County while [employees in the control room] were being assisted."[94] Later, both emergency officials and industry spokesmen agreed that the communications delay at Institute was "unacceptable," and Union Carbide announced that in the future it would notify officials immediately of any toxic accidents.[95] Experts on vapor-plume behavior, meanwhile, warned against overreliance on computerized dispersion models. "The main danger of a Safer-type system is believing the impressive picture created on the color graphics terminal without using judgment or looking out the window," one authority told *Datamation* magazine. Added another, "An ounce of prevention is worth a pound of cure. We should try to catch abnormal situations upstream in the manufacturing process *before* they erupt as leaks."[96]

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[92] Edward J. Joyce, "To Stop Another Bhopal," *Datamation* (March 1, 1986) 40-44.

[93] Wartzmann et al., 6.

[94] United States Environmental Protection Agency Region III Hazardous Waste Management Division, *Evaluation of Emergency Response to the August 11, 1985 Release of Hazardous Substances from Union Carbide's Facility in Institute, West Virginia* (Philadelphia, Penn., Dec. 1985) 2.

[95] Barry Meier, "Carbide Pledges Immediate Alert on Toxic Leaks," *The Wall Street Journal* (Aug. 19, 1985) 4.

The breakdowns and bungling that produced the Institute leak convinced many Americans that for Union Carbide -- and probably for the rest of the industry as well -- "abnormal situations" were all too normal. "In recent months, the chemical industry asserted that Bhopal was a unique aberration and that such a disaster could not happen here. That assertion, many industry experts say, has been undermined by Union Carbide itself," the *New York Times* summarized.[97] In the months after the Institute leak, stepped-up media coverage provided Americans with evidence that U.S. chemical plants were far more hazardous than had previously been believed. Union Carbide reported to a Congressional committee that there had been 190 minor releases of MIC and phosgene at Insitute between 1979 and 1984.[98] At Union Carbide's Texas City facility, 14 "major upsets" leading to airborne toxic releases had occurred in the first eight months of 1985 alone. A confidential EPA study obtained by reporters showed that there had been 6,928 chemical accidents in the United States between 1980 and 1985, causing 139 deaths and 1,500 injuries. In 35 of the incidents, operators had mishandled chemicals stored in large tanks -- the essential elements of the Bhopal and Institute accidents.[99] Citizens and local officials around the nation began to realize that their communities were ill-prepared for a serious catastrophe. In one New Jersey town, newspapers pointed out, a plant storing 20 tons of phosgene stood across the street from a day-care center.[100] Said Karim Ahmed, research director for the Natural Resources Defense Council, "Bhopal and Institute were warning signs. If they are not heeded -- and quickly -- people are just going to become sick of this industry."[101]

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[96] Joyce, 41-42. Emphasis added.

[97] Diamond, "Credibility a Casualty in West Virginia," E1.

[98] "Carbide Discloses More Toxic Gas Leaks in U.S.," *Chemical and Engineering News* (Feb. 4, 1985) 8.

[99] Stuart Diamond, "Problems at Chemical Plants Raise Broad Safety Concerns," *The New York Times* (Nov. 25, 1986) A1, D11.

Finally recognizing the depth of their public-relations problem, chemical manufacturers updated their stance on toxic hazards. Robert D. Kennedy, president of Union Carbide's chemicals and plastics group, admitted in 1986 that 'Institute was a turning point, especially on top of Bhopal. A year ago, a one-in-a-million shot was unthinkable. Now it's thinkable. It can happen here; it can happen anywhere. It causes us to rethink everything we do."[102] In 1985 the Chemical Manufacturers Association (CMA) had devised the Community Awareness and Emergency Response program (CAER), encouraging member companies to form voluntary evaluation teams consisting of plant managers, local officials, and hand-picked community members. The teams were to coordinate local emergency plans and provide the public with information on specific chemicals used at area plants. Two years later, however, only six states had operating CAER programs. Activists criticized management's dominance of the CAER teams, and proliferating state and federal laws requiring reporting of chemical hazards (discussed below) reflected the public's continuing doubt that the industry could regulate itself.

The CMA's "Responsible Care" program, established in 1988, was an expanded attempt to cap public concern. It required the CMA's 175 member companies to follow to a set of guiding principles including "To recognize and respond to community concerns about chemicals and our operations," "To report promptly to offials, employees, customers and the public, information on chemical-related health or environmental hazards and to recommend protective measures," and "To participate with government and others in creating responsible laws, regulations and standards to safeguard the community, workplace, and environment."[103] CMA President Robert Roland said of the program in 1991, "We are not asking the public to trust us. We are asking everyone to track us, to monitor our performance and make suggestions that will help us improve." Indeed, the unofficial motto of the Responsible Care program is "Don't trust us. Track Us."

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[100] Matthew L. Wald, "Industrial New Jersey Girds to Prevent Toxic Disasters," *The New York Times* (Nov. 26, 1985) A1, B4.

[101] Diamond, "Credibility a Casualty in West Virginia," E1.

[102] Diamond, "Problems at Chemical Plants Raise Broad Safety Concerns," D11.

But when activists at the U.S. Public Interest Research Group in Washington decided in 1992 to test the industry's commitment to this idea by contacting 192 CMA member facilities with a list of nine basic questions, the results were not encouraging. At 42 percent of the facilities, callers could not reach anyone to answer their questions, despite repeated attempts. At 27 percent, company officials could not or would not answer any of the questions. At only 17 percent of the facilities did company representatives answer each of the nine questions. (Officials at Union Carbide's facility in South Charleston, W. Va., refused to answer all questions, and nobody at the Institute plant would return the researchers' calls.) The group concluded that "Responsible Care may have made its way onto the pages of *Newsweek* and *People*, but it has not yet made its way inside the gates of the vast majority of chemical companies across the country."[104]

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[103] *Responsible Care®: A Public Commitment*, a brochure updated yearly and available from the Chemical Manufacturers Association, 2501 M Street NW, Washington DC 20037, (202) 887-1100.

After Institute the U.S. chemical industry could no longer claim that its plants were safer or its operators more competent simply because they were on American soil. Even in Chemical Valley, where residents fearing for their jobs had initially repudiated calls for strict safety crackdowns, community groups began to question manufacturers' commitment to reducing plant hazards. Community briefings held after Bhopal for 800 invited neighbors of Union Carbide's Institute plant were "a dog-and-pony show and totally inadequate," said Perry Bryant, director of the West Virginia Citizen Action Group.[105] "It is clear that people do not entirely trust the companies as reliable sources of information," said Lewis Crampton, a former EPA official and founding director of the industry- and government-sponsored National Institute for Chemical Studies in Charleston, W. Va. The organization's survey of the Kanawha Valley found that "local people want to have more information about chemical risks in their community, and they want the opportunity to register their concerns with public officials and with chemical plant managers."[106] After Bhopal and Institute, no amount of new safety equipment or talk of responsible care would relieve citizens' anxiety about the chemical industry's single-handed control over life-threatening technologies. Information and shared control were the two key antidotes, and if companies were not willing to provide them, then community activists and sympathetic legislators were ready to obtain them by force of law.

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[104] Carolyn Hartmann, *Trust Us. Don't Track Us. An Investigation of the Chemical Industry's 'Responsible Care' Program* (Washington, D.C: U.S. Public Interest Research Group, March 1992). The PIRG surveyors asked, or attempted to ask, the following questions: "(1) Can you tell me the names and quantities of chemicals that potentially cause cancer or birth defects that you brought into the facility last year? (2) Can you tell me what chemicals that may cause cancer or birth defects workers are exposed to at the facility? (3) Do you make products at the facility that contain chemicals that are toxic or could cause cancer or birth defects? (4) Can you tell me the names and amounts of toxic chemicals that go into the products you produce at the facility? (5) Can you tell me the neighborhoods through which you ship toxic chemicals or hazardous wastes? Can you send me a map or a schedule? (6) Have you had any accidents involving the transportation of toxic or hazardous chemicals to or from your facility in the past five years? (7) Has your facility made public its accident risk reduction plans? (8) Have you made available to the public internal emergency management plans, including worst case scenarios for accidental chemical releases? (9) Does your facility conduct toxics use reduction or source reduction planning? If yes, have you made available to the public your facility's toxics use reduction or source reduction plans or goals?"

[105] Ben A. Franklin, "Few West Virginians Go to Briefings on Union Carbide Plant," *The New York Times* (April 3, 1985) A22.

Winning and Using the Right to Know

The right-to-know movement in the United States sprang from the conflict between a basic democratic idea and the established reality of chemical industry autonomy. The idea is that lay citizens need detailed information about the toxic substances handled by local industries in order to explore the links between chemical emissions and health problems, to protect themselves against chemical accidents, and to create public pressure on industries to reduce chemical hazards. The reality -- as many citizens were astonished to discover when they first set out to find the information they wanted -- was that no law or government regulation required chemical manufacturers to provide publicly accessible data on the kinds, quantities, and dangers of the chemicals they used or emitted.[107] Often manufacturers themselves lacked a clear understanding of the amount of waste, pollution, and disease they might be generating through inefficiency and inattention to safety measures.

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[106] Lewis Crampton, "Living Together," *Chemtech* (June, 1989) 344-48.

[107] Of the thousands of toxic industrial chemicals contaminating the air and water in the United States, the Occupational Safety and Health Administration (OSHA) regulated only 22 as of 1990, and the Environmental Protection Agency only eight. Gary Cohen and John O'Connor, *Fighting Toxics: A Manual for Protecting Your Family, Community, and Workplace* (Washington, D.C.: Island Press, 1990) 20. The 1979 Comprehensive Environmental Response, Compensation & Liability Act, or Superfund, required that any spill of more than one pound of certain hazardous materials be reported to the EPA, but this information was not automatically available to the public.

These were simply "negative externalities," part of the reasonable risk needed to achieve reasonable profits, and until the nineteen-eighties public policy supplied few incentives to eliminate them.[108] Before the Bhopal catastrophe, in other words, the American political system had failed to address adequately the possibility that the chemical industry's tradition of trade secrecy might be incompatible with community safety and self-rule.[109]

But although Bhopal provided the crucial political boost necessary for the passage of federal right-to-know legislation, the effort to win access to corporate information on toxic chemicals had begun years earlier. The Philadelphia city council's enactment of the nation's first right-to-know law in 1981 capped a five-year citizen campaign to uncover the sources of alarmingly high cancer rates in the city's industrialized neighborhoods. The campaign succeeded, organizers believed, because it had combined the efforts of more than 40 groups, including the United Auto Workers, the League of Women Voters, Friends of the Earth, Americans for Democratic Action, and the Philadelphia Area Project on Occupational Safety and Health. "Opponents were unable to dismiss the right-to-know as simply a labor question or another item on a list of community concerns," wrote one organizer. "Nor were they able to effectively undercut our premise: in a city with one of the highest cancer rates in the nation, people should, at the very least, have a right to know the names of the chemicals to which they have been exposed."[110] The resulting legislation guaranteed public access to information on toxic chemicals used in Philadelphia and empowered the city government to regulate their storage and emission. By 1984, grassroots campaigns had contributed to the enactment of similar disclosure laws in 20 states, including New Jersey, New York, and California, and more than 40 cities, including Cincinnati, San Diego, and Sacramento. This patchwork approach meant, however, that citizens had different sets of rights in different communities and that manufacturers and distributors had to follow multiple and often conflicting regulations.[111] Federal courts also ruled that some state and local right-to-know laws were unenforceable, since they established reporting standards stricter than the federal government's.[112]

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[108] The economic term "negative externality," as I use it here, is similar to Ivan Illich's concept of "specific counterproductivity." Illich writes: "Specific or paradoxical counterproductivity is a negative social indicator for a diseconomy which remains locked within the system that produces it...[it is] an unwanted side-effect of increasing institutional outputs that remains internal to the system which itself originated the specific value. It is a social measure for objective frustration." *Medical Nemesis: The Expropriation of Health* (New York: Random House, 1976) 8. Toxic chemical emissions are clearly an unwanted and frustrating side effect of the system of chemical production, but it would be wrong to claim that they are "locked within" that system, as the success of right-to-know legislation in reducing emissions has demonstrated.

[109] But see Carl F. Cranor, *Regulating Toxic Substances: A Philosophy of Science and the Law* (New York: Oxford University Press, 1993) for an overview of the tort and regulatory law that does exist to control toxics.

At the same time, environmental groups advocating toxic waste reduction were learning that constructing an accurate overview of toxic chemical use or waste generation at any particular industrial facility was a nearly impossible task. "Industries didn't know very much about where or when or why they created waste," explains Paul Orum, coordinator of the national Working Group on Community Right-to-Know.[113] Detailed information appeared on waste-discharge permits required under the Clean Air Act, the Clean Water Act, the Resource Conservation and Recovery Act, and numerous other federal and state environmental laws, and this information was theoretically available for public review. But a study begun in 1982 by INFORM, a non-profit environmental research group based in Manhattan, found that "the information, while technically available, was logistically extremely difficult (occasionally impossible) to get access to. Mismanaged filing systems, multitudes of federal, state, and local-level record-keeping systems, and staff reluctance to make information available rendered data gathering an arduous task."[114] Once the data were in hand, moreover, inconsistencies in terminology and reporting requirements made comparisons between plants meaningless. INFORM did uncover one example of a systematic, comprehensive chemical inventory -- a study prepared by the state of New Jersey in 1979, then more or less forgotten -- and in 1985 the group proposed a national chemical survey based on the New Jersey model.

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[110] Caron Chess, "Winning the Right-to-Know," *Working Notes on Community Right-to-Know* (March, 1990) insert, page 4. Published by the Working Group on Community Right-to-Know, United States Public Interest Research Group, 215 Pennsylvania Ave., SE, Washington, D.C . 20003-1107.

[111] Jolie B. Solomon and Mark Russell, "U.S. Chemical Disclosure-Law Efforts Getting Boost from Tragedy in Bhopal," *The Wall Street Journal* (Dec. 14, 1984) 22.

[112] Janice R. Long and David J. Hanson, "Bhopal Triggers Massive Response from Congress, the Administration," *Chemical and Engineering News* (Feb. 11, 1985) 53-59.

[113] Personal interview.

The proposal came at a critical moment in the drive for national right-to-know legislation. When the 99th U.S. Congress convened in January, 1985, a month after the Indian gas catastrophe, preventing another Bhopal in the United States or abroad was one of the first items on its agenda. New York representative Stephen Solarz visited Bhopal and held a series of hearings on the health, safety, and environmental standards followed by U.S. multinational corporations doing business in developing countries. New Jersey Representative James Florio introduced a package of bills strengthening federal regulation of toxic substances and requiring companies to inform state and local officials about plant hazards. New Jersey Senator Frank Lautenberg included INFORM's plan for a national chemical survey in the proposed Emergency Planning and Community Right-to-know Act (EPCRA). Since Congress was also under pressure to reauthorize the 1979 Superfund law governing the cleanup of toxic-waste sites before the law expired in 1986, EPCRA proponents wrote the right-to-know provisions into the Superfund Amendments and Reauthorization Act, where they became known as SARA, Title III.

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[114] David Sarokin and Joanna D. Underwood, "The Toxics Release Inventory: The New Era of 'Right-to-Know' in the United States," *UNEP Industry and Environment* (July-Dec., 1990) 38-41.

The provisions provoked vehement opposition from chemical industry lobbyists, who persuaded many members of Congress that the Title III reporting requirements would be overburdensome for manufacturers and would inundate the public with information it lacked the technical knowledge to use. Even the Environmental Protection Agency opposed the right-to-know law, arguing that the voluntary "Chemical Emergency Preparedness Plan" it had created after Bhopal would be enough to help local communities guard against potential toxic hazards.[115] But on December 10, 1985, the crucial amendment creating a mandatory annual Toxics Release Inventory (TRI) survived House opponents' attempt to strip it from the Superfund reauthorization act by a vote of 212 to 211.

Right-to-know activists attributed their razor-thin victory to the fear and distrust generated by the accidents at Bhopal and Institute. Just weeks before the attempt to kill the TRI amendment, National Toxics Campaign Fund founder John O'Connor, an environmental health activist, had delivered petitions to Washington bearing two million signatures in the amendment's favor. "There's no question that people saw Bhopal and felt more vulnerable," O'Connor says today. "People picked up the phone or signed a petition because of Bhopal. The right-to-know section was the easiest issue to campaign on, because people thought they had that right already! They were shocked to find out that they didn't."[116]

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[115] The EPA's Chemical Emergency Preparedness Plan created a list of 405 acutely toxic chemicals and recommended that communities set up working groups to monitor their use. The working groups were to be similar to the CAER teams formed under the industry's Community Awareness and Emergency Response program. Skeptics, including Rep. James Florio, criticized the EPA's scheme because it failed to provide any sanctions against companies choosing not to cooperate. David J. Hanson, "Cooperation Key to EPA's Disaster Plan," *Chemical and Engineering News* (Jan. 6, 1986) 20-22.

David Allen, director of the Boston-based Center for Pollution Prevention and a long-time proponent of toxics-use reduction, agrees that Bhopal made 1985-86 the right time for right-to-know. "We never would have gotten that thing through without Bhopal," Allen says. "It was an accident of history. It was the coming of reason. Bhopal is what gave us the groundswell of public opinion that pushed it through Congress. People said, 'Gee, we need this information!' The chemical industry was under attack; its public opinion ratings went way down, and Congress acted. It wouldn't have had the political wherewithal to do it otherwise."[117]

In October, 1986, when Congress reauthorized Superfund by veto-proof margins of 386 to 27 in the House and 88 to 8 in the Senate, SARA Title III finally became law.[118] Among the law's many requirements were that the EPA draw up a list of extremely hazardous substances and threshholds for reportable releases of each; that plant operators immediately notify local and state emergency coordinators of releases above these threshhold quantities; that local emergency planning committees (LEPCs) be created to handle public information requests in all U.S. communities; that plant operators regularly submit "material safety data sheets" to the LEPCs describing their use of EPA-listed hazardous chemicals; that industries report routine releases of specified chemicals that might cause chronic health problems; that all material safety data sheets, toxic release forms, and emergency notices be made available upon request to the general public and that the LEPCs advertise this data's availability; and that citizens be allowed to sue plant operators or government officials for failure to carry out any of these provisions.[119]

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[116] Interview with the author at O'Connor's home in Cambridge, Mass., April 8, 1994.

[117] Telephone interview with the author from Allen's home in Somerville, Mass., March, 1994. The fact that knowledge of Bhopal had helped to ensure passage of the Community Right-to-Know Act as part of the Superfund reauthorization bill echoed the importance of another technological disaster, Love Canal, in the creation of the original Superfund in 1980. Writes sociologist Adeline Gordon Levine: "Love Canal was referred to frequently in congressional discussion [of Superfund], Love Canal residents and involved officials and consultants testified at legislative hearings, and Senator [Patrick] Moynihan publicly lauded the organized citizens of Love Canal...for their part in bringing the problem of toxic wastes to the national attention and for keeping it there." *Love Canal: Science, Politics, and People* (Lexington, Mass.: D.C. Heath and Company, 1982) 69.

[118] Joseph A. Davis, "Congress Clears 'Superfund,' Awaits President's Decision," *Congressional Quarterly Weekly Report* (Oct. 11, 1986) 2532.

The new law effectively repudiated the old regulatory system's reliance on permits, fines, and trust in favor of a massive experiment in grassroots democratic rule.[120] "Right-to-know is really the modern extension of the best democratic traditions the country has to offer," says O'Connor. "This is not an idea that was cooked up by experts at INFORM or some public policy think tank. It's thousands of people dying in the streets, and people saying 'There ought to be something in the Constitution!'"[121] Minnesota representative Gerry Sikorski, one of Title III's sponsors in Congress, called the legislation "a philosophical leap of faith -- kind of a heartfelt belief that people in communities have an absolute, fundamental right to know what goes into the air their kids breathe, the water they drink and the ground they play on."[122] Armed with this information, legislators hoped, lay citizens could mobilize public pressure to achieve what years of lawsuits and complex regulations had not: technological changes to reduce chemical plant hazards and minimize the use and abuse of toxic substances. But would it work? As Boston University law and technology scholar Michael S. Baram put it, "Will we achieve the Jeffersonian ideal of informed citizens who can take a responsible role in making public policy?"[123]

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[119] "Major Provisions of 'Superfund' Reauthorization Bill," *Congressional Quarterly Weekly Report* (Oct. 11, 1986) 2538-40.

[120] Environmental policy analysts Richard C. Rich, W. David Conn, and William L. Owens write: "It was in pursuit of the goal of reducing chemical hazards that Title III was innovative...Legislators apparently hoped that requiring firms to share data on their use of hazardous materials would both provide a vigilant public with the information it needed to monitor industry performance and cause industry to undertake voluntary risk reduction efforts in order to reassure citizens and prevent both legal actions and political pressure for more formal regulation." "'Indirect Regulation' of Environmental Hazards Through the Provision of Information to the Public: The Case of SARA, Title III," *Policy Studies Journal* (Vol. 21, No. 1, 1993) 16-34.

[121] Personal interview, April 8, 1994.

Jeffersonian or not, the political order that emerged with the right-to-know law was closer to direct democracy than anything the chemical industry had endured before. Manufacturers grumpily began a crash effort to meet Congress's July 1, 1988, deadline for compliance with the first Toxic Release Inventory. As Christopher Cathcart, the CMA's associate director for health, safety, and chemical regulation, complained, "There is some difficulty in releasing this information because of the possibility of its direct application to risk characterization."[124] Chemical makers feared, in other words, that the public would do with the TRI data exactly what Congress had intended it to do: embarrass the worst polluters into reducing annual emissions. But most companies complied anyway, and in 1989 the EPA released the first 300-page national TRI report.

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[122] Keith Schneider, "For Communities, Knowledge of Polluters Is Power," *The New York Times* (March 24, 1991) E5.

[123] Philip Shabecoff, "Industry to Give Vast New Data on Toxic Perils," *The New York Times* (Feb. 14, 1988); M. S. Baram, P.S. Dillon, and B. Ruffle, *Managing Chemical Risks: Corporate Response to SARA Title III* (Medford, Mass.: Tufts University Center for Environmental Management, 1990); see also Philip Shabecoff, *A Fierce Green Fire: The American Environmental Movement* (New York: Hill and Wang, 1993).

[124] David J. Hanson, "Industries Straining to File Toxic Release Data by Deadline," *Chemical and Engineering News* (June 20, 1988) 13-16.

The results startled the public. Some 9.6 billion pounds of toxic chemicals had been released into the air, water, and ground in 1987 -- 43 percent of it generated by chemical manufacturers, 19 percent by the metals industry, and the rest by paper manufacturers, petroleum refineries, vehicle manufacturers, electronics factories, and a variety of other industries.[125] Though this aggregate was huge in itself, the Office of Technology Assessment estimated that it covered only 5 percent of the nation's total toxic emissions. Admitted American Petroleum Institute president Charles J. DiBona, "Some of these numbers are going to sound absolutely frightening."[126]

Local media outlets and environmental groups quickly fastened on the report's listings of emissions from individual facilities. Residents of Northfield, Minnesota, for example, learned that Sheldahl, Inc., a local manufacturer of electronic circuit boards, had released 400 tons of methylene chloride into the air in 1987 -- enough to make it the United States' 45th-largest emitter of suspected carcinogens. Working with laborers at the Sheldahl plant, community groups persuaded the company to cut emissions as part of a new union contract.[127] The success stories accumulated as local citizens' groups aggressively put TRI data to new uses. Toxics-release information gave lay people a valuable bargaining chip in their bid to change industrial practices: the threat of bad publicity. In case after case, industrial managers remembered Union Carbide and gave in to community demands for hazard reduction:

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[125] Sarokin and Underwood, 40.

[126] Tim Smart, "Pollution: Trying to Put the Best Face on Bad News," *Business Week* (July 18, 1988) 76-77.

[127] John E. Young, "Keeping Tabs on Toxics," *World Watch* (May/June, 1992) 9, 33.

- In San Jose, California, the group Citizens for a Better Environment used 1987 TRI data to show that IBM's Silicon Valley plant discharged the third largest volume of ozone-destroying chloroflourocarbons in the nation. On Earth Day, 1989, 2,000 activists marched on the plant demanding a reduction in emissions. IBM agreed that autumn to phase out the use of CFCs in all products and processes by 1993.[128]

- Using TRI data showing that 65 companies in California's Contra Costa County stored a total of over 140 million pounds of extremely hazardous chemicals, Citizens for a Better Environment warned of the danger of a chemical catastrophe and pointed out that the county health department had failed to ask these companies for Risk Management Prevention Plans as authorized by state law. After a 1989 explosion at a local Chevron refinery spread a black cloud over residential areas, a coalition of activists convinced the county board of supervisors to force the still-reluctant health department to obtain the risk management plans.[129]

- The New Jersey Coalition Against Toxics used TRI data to identify five facilities in Berlin, New Jersey, as candidates for "good neighbor" agreements designed to prevent chemical accidents. Managers at Dynasil Corporation's Berlin glass factory, where a large fire had recently terrified nearby residents, invited the Coalition to tour their plant. The group's inspection report recommended fire hazard training and emergency showers for workers, new spill containment walls around outdoor storage tanks, sharing of emergency response information with the local fire department and emergency planning committee, and the installation of new sump pumps to keep rainwater from mixing with toxic silicon tetrachloride. Dynasil adopted all of the recommendations.[130]

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[128] Jeffrey Tryens, Richard Schrader, and Paul Orum, *Making the Difference: Using the Right-to-Know in the Fight Against Toxics*, a 1990 paper published by the National Center for Policy Alternatives, 2000 Florida Ave., N.W., Washington, D.C. 20009; page 1. Available from the Working Group on Community Right-to-Know.

[129] Ibid., 14.

- In a highly publicized report entitled "Local Error, Global Terror," the Massachusetts Public Interest Research Group used TRI data to show that the Raytheon Company had emitted 3.6 million pounds of CFCs, used to clean printed circuit boards, in 1987-88. Raytheon announced it would switch to water- and detergent-based cleaners by 1992, saying the MassPIRG report had "added an impetus" to this decision.[131]

- Residents of Boerum Hill, a South Brooklyn neighborhood, had complained for more than a decade of noxious odors from the Ulano Corporation, a graphic arts supplies manufacturer. 1988 TRI data showed that the company's emissions of toluene accounted for 17 percent of New York City's total toxic air pollution. On the same day that the Boerum Hill-South Brooklyn Clean Air Committee released these findings to the press, the New York State Department of Environmental Conservation ruled that Ulano must begin using a new incinerator to reduce toluene emissions by 95 percent.[132]

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[130] Ibid., 15; Susan Jaffe, "Bhopal in the Backyard?" *Sierra* (Sep./Oct., 1993) 50-52.

[131] Nita Settina and Paul Orum, "Making the Difference, Part II: More Uses of the Right-to-Know in the Fight Against Toxics," *Working Notes on Community Right-to-Know* (Sep./Oct., 1991) 1-8.

Although the Toxics Release Inventory is far more useful than any previous form of public information about the chemical industry (especially now that toxic-release data are available instantly via modem[133]), deficiencies in the original legislation limit its power. SARA Title III required that companies file toxic-release forms on only 328 hazardous chemicals, and no reporting was required at all if a company's total annual releases were under 10,000 pounds. Environmental policy analysts also point out that "if the 'regulation through information' strategy of Title III is to be effective in reducing chemical risks, the Local Emergency Planning Committees must succeed in alerting the public to chemical hazards and in providing them with the information they need to hold industry and its public sector regulators accountable."[134] Yet because Congress left the responsibility to fund the committees to the states, many LEPCs still lack the resources to make TRI data easily available or even to advise the public of its existence. LEPC members who participated in a recent study said they spent only 9 percent of their time "informing the public" or "seeking public input for the planning process," in contrast to 17 percent attending meetings and 32 percent "studying the issues." And while Title III mandated that the LEPCs' membership be broadly representative of their communities, the study found that affiliates of environmental and community organizations are outnumbered 5 to 1 on the committees by government and business officials. "As presently structured, LEPCs cannot be expected to serve as a catalyst for active public monitoring of local environmental risks," the study concluded.[135]

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[132] Ibid., 5.

[133] The EPA's official TRI database is maintained by the National Library of Medicine. Activists and public-interest organizations also use the Right-to-Know Network (RTK-NET) to exchange toxic release data, newsletters, and other resources. Information on RTK-NET, a project of OMB Watch and the Unison Institute in Washington, D.C., is available at (202) 234-8494.

[134] Rich, et al., 17.

Yet citizens' groups and sympathetic policymakers seem to have found ways around some of these limitations. The Clinton Administration has beefed up TRI reporting requirements by adding another 200 chemicals to the inventory and by requiring federal facilities (including those operated by the Department of Defense and the Department of Energy) to report the same information as private companies. In the Clean Air Act of 1990, Congress established a new "risk management planning program" that will eventually require 140,000 industrial facilities nationwide to disseminate worst-case scenarios explaining to workers and the public what could happen if safety systems fail.[136] The "Community Right-to-Know More Act" introduced by Representative Gerry Sikorski in the 1991-92 legislative season would have built on the TRI by adding 520 new chemicals to the inventory, requiring information from new kinds of polluting facilities, and collecting information on storage and production processes rather than simply on environmental releases. By that time the sense of urgency in Congress created by Bhopal had dissipated; the legislation stalled in committee because environmental groups "didn't muster the coalition" necessary to overcome industry opposition, according to right-to-know proponent Paul Orum. But the Administration is gradually putting pieces of Sikorski's bill into effect nonetheless.[137] Under the glare of TRI publicity, meanwhile, U.S. industries reduced total toxic emissions, as measured by the inventory, by some 30 percent between 1987 and 1992.[138]

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[135] Ibid., 31.

[136] The EPA is still studying ways of implementing this requirement. Paul Orum, "EPA Proposes Accident Prevention Rules," *Working Notes on Community Right-to-Know* (Sep./Oct. 1993) 1.

The World After Bhopal

Chemical manufacturing, until the nineteen-eighties, was one of the most lightly regulated industries in the United States. Managers boasted of the industry's comparatively low accident rate (6.5 injuries per 100 full-time workers in 1988, as against 12.1 injuries per 100 workers for all manufacturing industries[139]) and advocated voluntary safety programs instead of meddlesome government oversight. Legislatures and regulatory agencies traditionally allowed corporations to conceal as trade secrets the identities, quantities, and potential hazards of the chemicals they used in everyday production. Decisions about plant design -- including the choice of processes and chemicals used, the extent to which control should be automated, the presence or absence of safety monitoring devices, and the provision of emergency response plans -- were guided by industry practice and business priorities, not by outside pressure from lawmakers or citizens. After Bhopal, everything changed. In principle, if not in always practice, issues of safety, confidentiality, and design have been opened to community review on a scale that would have seemed impossible before the disaster.

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[137] "Key to the Revised Community Right-to-Know More Act," *Working Group on Community Right-to-Know* (Aug, 1992) 2; Notes from author's telephone interview with Orum from his office in Wasington, D.C., May 2, 1994.

[138] David Hanson, "Toxic Release Inventory: Firms Making Strides in Cutting Emissions," *Chemical and Engineering News* (May 31, 1993) 6-7.

[139] These figures do not include injuries to contract workers and may therefore mask a large number of accidents reported under different categories such as "construction." Nicholas Ashford, et al., *The Encouragement of Technological Change for Preventing Chemical Accidents: Moving Firms from Secondary Prevention and Mitigation to Primary Prevention* (Cambridge, Mass.: Center for Technology, Policy, and Industrial Development, Massachusetts Institute of Technology, 1993) III-10.

More than one group claims credit for these changes. In the words of Ronald Van Mynen, a Union Carbide vice president who led the company's technical and medical team to Bhopal after the disaster, "We concluded that an angry or frightened public could shut us down and realized that we faced two possible futures: We could be a severely regulated industry with limited growth potential, or we could be one that continues to carry out our traditional mission of innovation, of bringing new and better products to the public." Bhopal taught Union Carbide that "risk decisions are more likely to win public acceptance if the public shares in the decisionmaking" and purportedly inspired the company to launch "an all-out effort to involve the community in our actions."[140] Citizen organizers, of course, describe these changes somewhat differently. "People ought to be involved in their own fate -- that is the most important democratic inkling Americans have," says O'Connor. "Bhopal added a lot of impetus to community right-to-know and reinforced that people have got to use democratic structures to ensure that disasters won't happen."[141]

Change came only after much reflection and effort on both sides. In stressing the importance of their own efforts to reduce chemical hazards, however, industrial managers and activists alike forget the gripping power of the Bhopal disaster itself. As I have argued here, the political outcomes of technological failures are strongly shaped by the detailed character of those failures. It was not simply the fact of the Bhopal gas leak and its horrendous death toll but rather the *particular way* the disaster happened and the

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[140] Ronald Van Mynen, "View from the Top: After the World Changed," *Chemtech* (March 1992) 135.

[141] From the author's notes on an interview with O'Connor at his home in Cambridge, Mass., April 8, 1994.

systemic flaws in chemical process safety it revealed that led citizens to agitate for technical and operational reforms and managers to offer concessions in these areas. There could have been no more forceful demonstration than Bhopal of the vulnerability of host communities to catastrophic control failures at chemical manufacturing facilities.

The search for ways to avoid a recurrence has been a major preoccupation of environmental activism and legislative change over the last decade. Events after Bhopal, in other words, have been largely driven by events *at* Bhopal: an assertion which this chapter has documented. Citizen knowledge of technological catastrophes is inherently politicizing and can help redress, if not fully reverse, imbalances in the decision-making power held by different social groups. Understanding how this happened after Bhopal might prepare us to cope with the next catastrophe more proactively.

Will history after Bhopal come full circle -- will the right to know someday find its way to India? Canada will implement a TRI-like program this year, and the United Kingdom, Sweden, France, and Australia have plans to establish their own public chemical inventories based on the American model. At the 1992 Earth Summit in Rio de Janeiro some 150 nations signed "Agenda 21," a development blueprint calling for global emissions inventories and the phaseout of some toxic chemicals. Public interest groups in several countries have requested TRI-equivalent data from international chemical companies, with some success.[142]

But if the democratic ideas behind the U.S. Community Right-to-Know Act can be put to work in India, the world's largest democracy, the incongruity of the fact that an *Indian* disaster enhanced safety and democratic participation in the United States might begin to be righted. "Community right-to-know provisions have received a considerable boost in the United States after Bhopal. It is to be hoped that the governments of developing countries will recognize the need for similar guarantees for their citizens," writes Sheila Jasanoff. She warns, however, that "efforts to lobby for such legislation in India will almost certainly run up against the predisposition toward governmental secrecy that marks India's traditions of public administration. There is little reason to expect that government agencies will set the presumption of confidentiality aside in future policy-making with respect to hazardous technologies."[143] Jasanoff further points out that Third World governments are reluctant to do anything to discourage continued technology transfer and industrialization. The impetus for democratic technological change in India and other developing countries, then, must come from citizens themselves. While technology-exporting countries like the United States can enact laws requiring companies to warn foreign governments about industrial hazards, it falls to the technology-importing nations to ensure that those hazards are respected, and only where governments are accountable to their people will this occur.

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[142] "Emissions Inventories Develop Internationally," *Working Notes on Community Right-to-Know* (May/June, 1993) 3.

Even in the so-called "developed" nations, meanwhile, right-to-know laws provide no perfect shield against technological catastrophe; As T.H. Huxley asked in 1877, "If a little knowledge is dangerous, where is the man who has so much as to be out of danger?"[144] Explosions that killed 23 workers at a Phillips refinery in Pasadena, Texas, in 1989 and 17 workers at an Arco petrochemicals complex in Channelview, Texas, in 1990, *in spite of* updated safety technology, showed how deeply-rooted and resistant to cosmetic change are the causes of most modern industrial disasters.[145] Only in a few isolated cases have community groups, local emergency planning committees, workers, and plant managers cooperated to conduct the kind of top-to-bottom safety reviews needed to identify and reduce vulnerabilities in a facility's technological and organizational structure. Although work is underway to shift the emphasis in chemical accident regulation from "secondary prevention" (reducing the probability of an accident) to "primary prevention" (deploying inherently safe technologies that prevent the *possibility* of an accident)[146], the right-to-know approach remains a remedial strategy. It limits citizens to *(a)* discovering what substances have already been emitted by industry and *(b)* pressing for incremental technological modifications to reduce, not really eliminate, toxic hazards.

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[143] Jasanoff, 1122, 1119.

[144] T.H. Huxley, *On Elementary Instruction in Physiology* (1877).

The right-to-know, in other words, is a reactive right, not proactive one. As Jasanoff writes of the Bhopal disaster, "knowledge would have been most beneficial at the time Union Carbide made its basic decision about what manufacturing process should be employed in Bhopal," not after thousands had already been exposed to corrosive doses of MIC.[147] In the same way, data like those gathered in the Toxics Release Inventory would be more useful in the form of environmental-impact projections allowing communities to debate proposed technological projects on their social, economic, and ecological merits, rather than in the form of dry reports issued after those projects have already been completed and are affecting their environments.

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[145] Susan Ainsworth and Wil Lepkowski, "Arco Plant Explosion: Many Casualties, Markets Disrupted," *Chemical and Engineering News* (July 16, 1990) 4-5.

[146] Nicholas A. Ashford, et al., *The Encouragement of Technological Change for Preventing Chemical Accidents: Moving Firms from Secondary Prevention and Mitigation to Primary Prevention* (Cambridge, Mass.: MIT Center for Technology, Policy, and Industrial Development, July 1993).

[147] Jasanoff, 1122.

But despite their limitations, the Toxics Release Inventory and other varieties of right-to-know legislation have already shifted the balance of political power between U.S. chemical producers and citizens. More than Chernobyl (which helped spark a general social conflagration with tentatively democratic results) and more than Three Mile Island (which ended in a stalemate that will be resolved only after decades of nuclear plant attrition), the Bhopal catastrophe has fostered a tangible rejuvenation of democracy -- or at least a kind of stopgap substitute for it. As William Greider has written, "Against these bleak facts [that the system of electoral politics has been corrupted by big money, that a few powerful corporations and lobbying organizations dominate policymaking], there is a crucial contrary truth, one that is seldom acknowledged and, therefore, not widely understood. It is this: The nation is alive with irregular political energies, despite the failure of formal electoral politics. Citizens of every stripe and status do engage themselves one way or another in trying to move the public agenda, despite all the impediments."[148] In the age of large, centralized technological systems, true democracy may be no more realistic a possibility than perfect safety, but grassroots forms of political representation are emerging to fill the gap between the ideal and the real. Right-to-know laws are one such form, and although it took a disaster to get them enacted, they may yet become part of a broad new pattern of public involvement in the control of complex technologies.

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[148] William Greider, *Who Will Tell the People? The Betrayal of American Democracy* (New York: Touchstone, 1992) 23-24.

Chapter 5

A CRIMSON INCANDESCENCE

Chernobyl and the Fall of the Soviet Union

Hope,
crowned by Nobel,
like a dreadful genie
woke above Chernobyl.
Forgive me, those who
shut the crack
with their own bodies.
Who is to blame --
Humanity or Science?
...And if man is
the image of God
Is God -- my image?

— Andre Vosnesensky
published in *Pravda*, 1987[1]

The people of the former Soviet Union asserted their freedom bit by bit as *glasnost* gradually exposed the weakness, corruption, and bloody history of the Communist Party. But if this process of awakening and recognition had a discrete beginning, it came at 1:23 a.m. on April 26, 1986, when reactor No. 4 of the state-run V.I. Lenin Atomic Energy Station at Chernobyl disintegrated in a blast of steam, flaming graphite, and deadly radionuclides. The explosion was no accident, the Soviet people came to understand, but simply another malignant product of the Communist apparatus that controlled nuclear power along with everything else in Soviet life. "Chernobyl was not *like* the Communist system. They were one and the same," said Yurii Shcherbak, a leader of the new Ukrainian environmental movement.[2] Fusing technology and politics, the disaster came to symbolize the Soviet Union's long history of environmental abuses and frightened many Soviet citizens into their first open defiance of the state. Angry scrutiny of the nuclear industry led to a moratorium on plant construction and set a pattern for the renunciation of Communist power itself. Russian physicist Valerii Legasov was one of many who helped bring about this transformation, and though he did not live to witness the empire's fall, his story is a microcosm of the Chernobyl revolution.

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[1] Quoted in Armand Hammer and Robert Peter Gale, "The Lessons of Chernobyl, One Year Later," *The New York Times* (April 26, 1987) E31.

[2] David Remnick, *Lenin's Tomb: The Last Days of the Soviet Empire* (New York: Random House, 1993) 245.

At 6:00 p.m. on April 26, 1986, a cavalcade of black government limousines awaited the Aeroflot jet as it taxied to a halt on tarmac at Kiev airport. This special flight from Moscow carried some very important passengers; a crowd of Ukrainian officials, ashen-faced, watched anxiously as they emerged. One of the passengers rushed up to the officials. It was Legasov, First Deputy Director of the Soviet Academy of Sciences' Kurchatov Atomic Energy Institute, where the high-power boiling channel-type reactor -- RBMK, in Russian parlance -- had been invented. Any more news of the accident? Legasov demanded. Nothing exact, the officials replied, but the situation was bad. It was best that they proceed to the site directly. The delegation piled into the limousines and sped north to Pripyat.

Just six hours earlier, Legasov had been appointed scientific director of a government commission hurriedly assembled to evaluate the situation at the V.I. Lenin Atomic Energy Station in Chernobyl. Someone had pulled him from a Party organizational meeting to tell him of the accident. By then, more than ten hours had passed since the apparent explosion inside one of the station's four 1000-megawatt reactors. (Another 30 hours would go by before the detection of a radioactive cloud over Sweden would alert Western nations to the disaster). Legasov had rushed back to the Institute to find Aleksandr Kuligin, head of the RBMK section, and then to Vnukovo airport, where he met the leader of the government commission, Deputy Chairman of the Council of Ministers Boris Shcherbina.

The creation of an emergency commission was the Soviet Politburo's normal response to a major natural or industrial disaster. Shcherbina, a former minister of construction in the gas and oil industry, was an innocuous choice to head the Chernobyl team, someone with a profile low enough to avoid attracting attention to the incident. Legasov, by contrast, was "clearly the most qualified man in the world to compile the documentary record of the causes and consequences of the accident"[3] -- a graduate of the Mendeleev Institute's prestigious Faculty of Physicochemical Engineering, former Deputy Director of the All-Union Institute of Chemical Physics, Radiochemistry, and Nuclear and Plasma Technologies, and an expert on nuclear fuels. Not coincidentally, perhaps, the 51-year-old Legasov also favored the rapid expansion of the Soviet nuclear energy program and was a strong defender of the safety of Soviet nuclear plants. In 1979 he had written an article asserting that the Three Mile Island accident was "irrelevant" to the Soviet nuclear enterprise because Soviet safety standards were higher than those in the United States and because Soviet plant operators were better trained and educated than their American counterparts.[4]

Shcherbina, Legasov and the rest of their team arrived at Pripyat after dark that evening. The town, 20 kilometers north of the atomic plant itself, had been built from nothing in the middle of this sandy, marshy, non-arable region of rural Ukraine to house tens of thousands of Chernobyl workers and their families. Local officials now informed the commissioners (as recorded by Legasov) that "In the course of conducting an irregular experiment...two consecutive explosions had occurred in the fourth block of the station. The reactor building had been destroyed and several hundred people had received radiation injuries...Two people had died and the others were in the town hospitals...The radiation level in Pripyat was significantly raised, but it did not yet represent a grave danger to the population." Shcherbina assigned Legasov to coordinate measures to "localize" the accident, but nothing could be done until the next morning, when helicopter units reported the extent of the damage. "It was evident on the first flight that the reactor was completely destroyed," Legasov reported. "Pieces of the graphite blocks, either whole or in bits, were scattered about on the roofs of the machine hall and over the whole area...A white column several hundred meters high consisting of the products of the fire (apparently graphite) was constantly being emitted from the reactor crater. Inside the reactor space one could see separate huge spots of crimson incandescence."[5]

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[3] Zhores A. Medvedev, *The Legacy of Chernobyl* (New York: W.W. Norton & Company, 1990) 19.

[4] Medvedev, 272-73.

Legasov's first job was to stop any further deterioration of the reactor core. Since the control rods had been destroyed in the explosion and the core was no longer being cooled by the normal circulation of water and steam, it was entirely possible that an uncontrolled fission reaction was going on inside the devastated reactor. Rising temperatures from fission could lead to another explosion or even a meltdown. After firefighters from the Ukrainian Ministry of Energy made three unsuccessful attempts on April 27 to douse the graphite fire with water, Legasov and the other scientists on the commission ordered that the reactor be smothered with loose solids. That day and the next, 279 helicopter sorties dropped several hundred tons of sand, clay, lead, dolomite, and boron carbide into the reactor building. The physicists hoped the material would quell the fire, cool the core, inhibit fission by absorbing stray neutrons, and filter out poisonous decay products before they entered the atmosphere. At first, the strategy seemed to work. As helicopter sorties continued, radionuclide emissions declined from 4 million curies (MCi) on April 27 to 2 MCi on May 1.[6]

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[5] The passage is from Legasov's memoirs, published in *Pravda* on May 10, 1988, and is quoted in Medvedev, p. 51.

But in fact the helicopter pilots were dumping the quenching material in the wrong place.[7] Almost none of it entered the burning reactor core, where the temperature crept back upward. By May 5 the daily release of vaporized radionuclides had increased to 8-12 MCi -- nearly as much material as was ejected in the original explosion.[8] An evacuation of the 30-kilometer-radius "exclusion zone" around Chernobyl had begun on May 3, but the hundreds of emergency workers and scientists scrambling heroically to contain the accident were left to absorb huge doses of radiation. On May 4, when Shcherbina and the rest of the government commission flew back to Moscow for treatment at a clinic specializing in radiation sickness, Legasov stayed behind.

He and his colleagues were mystified when radioactive releases from the core suddenly plummeted to less than 150,000 curies on May 5. Scientists later speculated that debris from the reactor fuel elements had undergone a second meltdown and burned through to the vault beneath the reactor, where it was cooled by emergency injections of liquid nitrogen. By Victory Day, May 9 -- the anniversary of the defeat of Nazi Germany -- "It seemed to us that Unit 4 had ceased to breathe, burn, live," Legasov wrote. The physicists at the site were eager to celebrate, but events inside the core spoiled the holiday. As some of the physicists had feared might happen, the still-burning floor of the reactor core collapsed, raising a huge cloud of radioactive dust that caused radiation measurements to shoot up even as far as 60 kilometers from the plant. After Legasov ordered that another 80 tons of lead be dropped into the crater, however, the fire was finally extinguished.[9] The core was still hot and extremely radioactive, but radionuclide emissions had largely ceased.[10]

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[6] A curie (abbreviated Ci) is a unit used by physicists to measure the amount of energy given off by a piece of radioactive material. One curie equals 37 billion atomic disintegrations per second. A person holding one gram of radium in his hand for one second would be exposed to one curie of radiation (about 888,000 ergs) -- 16 times the fatal dose.

[7] A fact recently brought to public attention by Alexander R. Sich, author of a 1994 doctoral dissertation in the MIT Department of Nuclear Engineering. See Sich, *The Chornobyl Accident Revisited: Source Term Analysis and Reconstruction of Events During the Active Phase* (Unpublished Ph.D. dissertation, Massachusetts Institute of Technology, Jan., 1994) 3-4, 239-249; David L. Chandler, "Study Says Chernobyl Core Melted Down," *The Boston Globe* (Jan. 30, 1994) 1, 12; David L. Chandler, "Chernobyl: What Really Went On During Those 10 Harrowing Days," *The Boston Globe* (Jan. 31, 1994) 25, 28-29.

[8] Medvedev, 53-57, 59.

The accident's tentative resolution marked the beginning of a two-year odyssey for Legasov. Initially, the physicist stood by the Soviet scientific and military establishment's unswerving commitment to nuclear energy. "I am profoundly convinced that atomic energy stations are the pinnacle of achievement of power generation," he had told *Pravda* in June, 1986. "They are not only economically advantageous compared to thermal stations in normal use and not only cleaner ecologically, but they are the preparatory basis for the next technological leap. The future of civilization is inconceivable without the peaceful utilization of nuclear power...People have been killed [at Chernobyl] but I am convinced that nuclear power will come out of this test even more reliable."[11] Legasov went on to suggest that nuclear power could become a stabilizing influence in world politics as competition over dwindling fossil-fuel resources heightened.[12] As the leader of a 28-member Soviet delegation to the International Atomic Energy Agency's annual session in Vienna in August 1986 and co-author of the official report on Chernobyl presented there, he admitted that the actions of the plant's operators leading up to the accident had been "awkward and silly" but he defended the basic design of RBMK reactors, saying they were easier to build and more economical than the alternatives.[13]

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[9] Medvedev, 64-65.

[10] Even at the end of May, however, daily radionuclide emissions were still higher than the *total* release from the Three Mile Island accident. Emissions did not cease altogether until the completion of the sarcophagus in October. Medvedev, 80.

[11] Quoted in David Marples, *Chernobyl and Nuclear Power in the USSR* (New York: St. Martin's Press, 1986) 176.

Sometime after the Vienna meeting, however, Legasov began to question the basic doctrines guiding Soviet nuclear development.[14] He commented that the promise demonstrated by the first, small RBMK reactors built in the nineteen-sixties had darkened when the technology was indiscriminately scaled up to meet national electricity demand. (This crash program to increase Soviet reactor output parallelled the post-Sputnik acceleration of research on nuclear power and space exploration in the United States; see Chapter 3.[15]) "The problem today is the proliferation of all sorts of [nuclear] sites and the concentration of vast power," Legasov told Ukrainian environmentalist Yurii Shcherback in a 1987 interview. "It was necessary quickly to introduce and master new scales of power...The number of people busy with the preparation of installations and their running increased sharply. But the teaching and training methods could not keep up with the rate of development."[16]

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[12] David Marples, *Ukraine Under Perestroika: Ecology, Economics and the Workers' Revolt* (New York: St. Martin's Press, 1991) 23.

[13] Richard L. Hudson, "Experts Stunned by Soviet Nuclear Laxity," *The Wall Street Journal* (August 29, 1986) 21.

[14] Ukraine scholar David R. Marples relates Legasov's story in his 1991 study *Ukraine Under Perestroika*. Marples' first two Chernobyl books were *Chernobyl and Nuclear Power in the USSR* (1986) and *The Social Impact of the Chernobyl Disaster* (1988).

[15] See also chapter 7 in Brian Balogh, *Chain Reaction: Expert Debate and Public Participation in American Commercial Nuclear Power, 1945-1975* (Cambridge, U.K.: Cambridge University Press, 1991) 171-220.

In the published memoirs of his Chernobyl experience, Legasov bitterly criticized the lack of emergency preparedness, medical services, and dosimetric equipment at the site. He asserted that accidents were far too common at Soviet atomic energy stations. "Frequent leaks...badly working valves...all these took place every year...Anyone who has been in an atomic energy station building site is amazed that one can do such highly responsible work at such shoddy building sites."[17] In 1988 Legasov told a journalist for the *Moscow News* that he was now "convinced" that any of the USSR's 14 other RBMK reactors could easily suffer a Chernobyl-type failure. "The most important contributing factors to the Chernobyl accident have not been and cannot be removed," he stated. "They include faults resulting from poor construction and lack of reliable emergency systems for similar plants, and the impossibility of constructing concrete 'cones' to seal them at this stage."[18]

More than simple whistleblowing, Legasov's increasingly frequent public statements in 1987 and 1988 amounted to a deep critique of Soviet officialdom's blind infatuation with advanced technology. While battling the radiation sickness that had begun to weaken him physically, he simultaneously challenged his colleagues in the Soviet technocracy to rethink their notions of industrial safety. "We have become too carried away by technology," he said.[19] "The accident[s] at Chernobyl, at Three Mile Island, and other tragic events not connected with the peaceful atom, for example, the explosion of the *Challenger* spaceship, the explosion [sic] in Bhopal, India, catastrophes at sea and on the railroad, have demonstrated to us that the problem of the interrelationship between people and the machine has still not been fully resolved and demands our tireless attention. The enemy is not technology itself, but our incompetence, our irresponsibility in dealing with it."[20]

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[16] Yurii Shcherbak, *Chernobyl: A Documentary Story* (London: MacMillan Press Ltd., 1989) 149-150.

[17] Quoted in Medvedev, 268-69.

[18] Interview with Ales Adamovich in *Moscow News*, no. 29, 1988; quoted in Marples, *Ukraine Under Perestroika*, 24.

[19] Ibid., 24.

Legasov's emphasis on operator error in his report to the IAEA had given way to an awareness of the ideological and institutional roots of the disaster, and of the need for a fundamental reassessment of the country's technological goals. Legasov now urged a return to engineering enterprises carried out "in the spirit of the great humanitarian ideas."[21] He told Shcherbak, "If someone is educated only in technical ideas, he can only reproduce technology and perfect it...the general key to everything that has been happening is that we have for a prolonged period been ignoring the role of the moral principle [in technology]: the role of our history and of our culture."[22]

For his efforts Legasov earned the resentment of many of his fellow academicians. His ideas for reform were, in the words of Ukraine scholar David Marples, "rebuffed and rejected at every turn." One skeptical senior researcher at the Kurchatov Institute dismissed Legasov as "a typical representative of the scientific mafia whose politicking brought about the Chernobyl tragedy, thereby injuring the country more than the mafiosi who dealt in corruption."[23] On April 26, 1988, the second anniversary of the accident, the Soviet Academy of Sciences formally rejected by a vote of 129-100 Legasov's plan to rework the principles of industrial safety in the USSR. The next day, Valerii Legasov committed suicide.

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[20] Quoted in Marples, *The Social Impact of the Chernobyl Disaster*, 259.
[21] Marples, *Ukraine Under Perestroika*, 24.
[22] Shcherbak, 152-153.
[23] Ibid., 24.

The Soviet press did not report Legasov's death until three weeks later, but on May 20, 1988, in a sign of the growing openness which Legasov himself had helped to foster, *Pravda* posthumously published his Chernobyl memoirs under the title *Moi dolg rasskazat ob etom* -- "My duty to tell about this."[24] The memoirs revealed a great deal about the bungled official response to the accident and shockingly lax safety standards within the Soviet nuclear industry. They did not, however, pinpoint the sources of Legasov's own remarkable about-face on these issues. Had the accident's horrors prompted Legasov to revise his personal and professional beliefs about the Soviet nuclear program? Or had they simply created enough political room for him to express long-concealed doubts about RBMK safety? Had he, at the end of his life, been overcome by radiation sickness and the burdens of professional ostracization, or was his suicide an attempt to make a final statement that might sway the Soviet nuclear establishment from its disastrous course? The answers died with him.

Legasov ended his life just as the Soviet Union's enforced consensus on nuclear power was beginning to unravel -- as was the Soviet state itself. Accurate information about Chernobyl's causes and consequences began to reach the Soviet public early in 1988, in a wave of newspaper and magazine articles made possible by the lifting of press restrictions under *glasnost* (openness). Opposition to nuclear power surfaced even in remote rural areas like the Khmelnitsky oblast (district) of Ukraine, where a huge complex of nuclear reactors was under construction. "Workers, school teachers, and low-level bureaucrats... were swept into a frenzy of anti-nuclear activism," writes Jane Dawson, an American political scientist who visited the region. The specter of Chernobyl "dragged them out of their long lethargy and into a determined, angry crusade against those government organs who would impose nuclear power on their oblast."[25]

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[24] Valerii Legasov, "Moi dolg rasskazat ob etom," *Pravda* (May 20, 1988), reprinted in *Fantom: Sbornik Dokumental'nykh I Khudozhestvenykh Proizvedenii O Tragicheskih Sobytiiahkh Na Chernobyl'skoi A.E.S.* (Moscow: Moldai Gvardiia, 1989) 7-20.

The story was repeated all over the Soviet Union, where nuclear energy came to be despised as both source and symbol of state-prescribed misery. Central Committee plans called for a doubling of nuclear power between 1986 and 1991, but during that time not a single new reactor was commissioned and opponents halted construction on 39. Among a people once cowed into passivity by Lenin's Red Terror, Stalin's purges, and decades of Party repression, this kind of resistance was unprecedented. Anti-nuclear activism, however, would be only the first phase of the upheaval. The Soviet people were engaged in nothing less than the collective withdrawal of their consent to be governed.

Valerii Legasov was thus only one among millions whose lives were set on a new course by the Chernobyl disaster. But his story is unique because it has since been echoed, at least in its broad contours, by the fate of the Soviet nuclear industry, by the fall of Soviet Communism, and by the collapse of the Soviet Union itself. Despite adherence to the Party line in some quarters, the accident opened to question the entire design and operating philosophy of the Soviet nuclear program.[26] It demonstrated the inherent dangers of the

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[25] Jane Irons Dawson, *Social Mobilization in Post-Leninist Societies: The Rise and Fall of the Anti-Nuclear Power Movement in the USSR* (unpublished Ph.D. dissertation, Department of Political Science, University of California at Berkeley, 1993) 194-95. Provided courtesy of the author.

[26] David Marples reports that a minority of Soviet nuclear scientists had had longstanding doubts about RBMK safety, but that authorities' initial response to the disaster reflected only the views of staunch proponents of the design. "KGB archives reveal that throughout the nineteen-seventies, scientists were concerned about station flaws, from the combustible

RBMK system and the astonishing arrogance with which designers and operators invited disaster. It exposed a pattern of technological optimism and complacency about health and environmental hazards that was foolhardy to the point of absurdity. And it showed that the Party bureaucracy in Moscow was more concerned with controlling information about the disaster than with mitigating its consequences. Moreover, the accident occurred at a crucial moment in the evolution of Soviet society, when *perestroika* was as yet little more than a proposal but pressure for political independence in the republics was growing rapidly. It thus provided both environmentalist democrats and conservative nationalists with a powerful lever for change.

The dissolution of the USSR shortly after the abortive coup of August, 1991, was a kind of consensual state suicide in which the various republics agreed to sever the ties, especially those of Soviet Communism, which had bound them for so long. This moment might not have come with such swiftness and finality if not for the Chernobyl disaster's political repercussions in Ukraine, Belarus, Lithuania, Russia, and other republics. Just as it drove Valerii Legasov to end his own life, I intend to show, the Chernobyl disaster helped hasten the demise of the Soviet Union as a nation and as an idea. It was Lenin's famous formula that "communism equals Soviet power plus electrification of the entire country," but today it seems that communism plus nuclear-generated electric power equaled Soviet disintegration.

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bitumen on its roof to serious faults with the control rods...the RBMK was known to be unstable when operated at low power...[but] in fact, the Soviet authorities were proud of the reactor...The accident had been 'contained,' went the party line...The government had acted promptly and efficiently in dealing with the evacuation, decontamination, and sealing the fourth reactor." Marples, "Chernobyl's Lengthening Shadow," *Bulletin of the Atomic Scientists* (Sep., 1993) 38-43.

This chapter will document aspects of the Soviet nuclear program, of the disaster itself, and of reform movements in Ukraine and elsewhere that combined to make Chernobyl such an important vehicle for change. My assertions here may be more controversial than those of the previous chapters; while many writers have recognized that the Chernobyl disaster helped transform the political landscape of the Soviet Union, few have argued that the catastrophe was central to the collapse of the Communist regime. It is my contention that Chernobyl changed Soviet citizens' ideas about the competence and credibility of the Soviet state in ways that guaranteed the acceleration of the Gorbachev's early reforms -- reforms that eventually destroyed the USSR and dwarfed the democratizing changes emerging from Three Mile Island or Bhopal.

This is by no means to claim that the people of the former Soviet republics would be *worse off* today if the explosion at Chernobyl had never occurred. The accident spread radiation and sickness across a vast area; millions of acres remain too radioactive to farm, and the death toll, already in the thousands, will grow by thousands more as fallout-induced cancers appear over the coming years and decades. Moreover, the Communist Party would doubtless have lost power eventually, and whether one more year or ten had intervened before the final convulsion, the future of democracy in Russia and the former republics would remain uncertain, beclouded by persistent economic chaos and the danger of takeover from the far right. But the Chernobyl disaster *did* happen, and eight years later it is possible to say that no single unplanned event was more destabilizing for the old regime or created a greater opportunity for citizen involvement in technological and political affairs. That is the story I want to tell here: the one Valerii Legasov started but did not live to finish.

Technological Gigantism

The notion that nuclear power plants are inherently hazardous facilities whose siting and planning should be subject to local review gained widespread currency in the Soviet Union only after the accident at Chernobyl. Before the disaster, only a tiny group of urban writers and intellectuals had dared to express opposition to the Soviet nuclear program.[27] (The equivalent was not quite as true in the United States, where anti-nuclear groups boasted a sizable following even before Three Mile Island; nonetheless, many people considered these groups part of the "radical fringe" until TMI, when the bulk of the public turned against nuclear power.) The ideology guiding the Soviet government's development of nuclear power precluded both a realistic estimate of the technology's dangers and any possibility of citizen involvement in preventing or mitigating them. That the old regime would fall victim to reform pressures stemming in part from the nuclear disaster was a kind of justice, for the RBMK was the product of a nuclear program that owed both its form and its flaws to Soviet politics.

From the beginning of the Soviet state, its leaders distinguished themselves by their commitment to what has been called "technological gigantism."[28] The key to achieving a strong communist society, Lenin believed, lay in rationalized mass-production processes. He was fascinated by

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[27] Jane Dawson writes, based on her 1990 interview with environmental leader Yurii Shcherbak, that "opposition to nuclear power simply did not exist among the general population prior to Chernobyl." See Dawson, *Social Mobilization in Post-Leninist Societies,* 163.

[28] See Paul Josephson, "The Historical Roots of the Chernobyl Disaster," *Soviet Union/Union Sovietique* (Vol. 13, No. 3, 1986) 275-299; Loren Graham, *The Ghost of the Executed Engineer: Technology and the Fall of the Soviet Union* (Cambridge, Mass.: Harvard University Press, 1993); Nikolai Nikolaevich Vorontsov, "Nature Protection and Government in the USSR," *Journal of the History of Biology* (Fall, 1992) 369-384, esp. 378-83.

Fordism, the standardized assembly-line methods that had made Henry Ford's Detroit auto plants so efficient, and by Taylorism, the "scientific management" of the labor process developed at the turn of the century by American Frederick W. Taylor. Science and technology, Lenin hoped, would guarantee the success of the Bolshevik Revolution by harnessing the Soviet Union's vast manpower and natural wealth for continuous economic growth and social progress.[29]

But the large construction projects of early Soviet history were neither rational nor efficient; instead they belied a commitment to grandiosity for its own sake. Dneprostroi, a huge hydroelectric dam built on the Dnieper River during the First Five-Year Plan, displaced thousands of farmers from its flood plain and was too far from centers of electrical demand to transmit power efficiently, but Stalin and other leaders "wanted the largest power plant ever built in order to impress the world and the Soviet population with their success and that of the coming Communist social order," according to Loren Graham, a historian of Soviet science and technology.[30] Thousands of enslaved peasant laborers died building Magnitogorsk, a steel manufacturing complex begun in 1929 as the Soviet answer to U.S. Steel's massive mills in Gary, Indiana, but within forty years the depletion of nearby ore deposits turned the plant and the surrounding city into an economic disaster area. The construction of Belomor, the canal that fulfilled the dreams of Peter the Great by linking the Baltic and White Seas, was an equally monstrous waste of lives and resources. Prison laborers "completed" the canal in 1933, but it was frozen half the year, often dry the other half, and too shallow for oceangoing vessels. Its locks and embankments had been cobbled together from wood and rocks, and the entire canal had to be rebuilt after the Second World War.[31]

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[29] Josephson, 289-293.

[30] Graham, *The Ghost of the Executed Engineer*, 52.

Unfortunately, Soviet planners learned little from these mistakes. In its early decades the Soviet Union was swept up in a single-minded campaign to subdue Nature for the glorification of the state. Popular mottoes like "to destroy means to create" and "the smoke of factories and plants is the breath of the Soviet republic" summed up this malignant strain of technological enthusiasm. Belomor, Dneprostroi, and Magnitogorsk were all products of the government's "great transformation of nature in the interest of socialist construction."[32] As former Minister of the Environment of the USSR Nikolai Vorontsov has written, "The entire ideology of the five-year plans was based on the idea that the country must leap forward at any price, linked with the necessity of immediate militarization to defend the world's lone outpost of socialism, threatened by 'capitalist encirclement.' It was assumed that natural resources were for all practical purposes infinitely available to meet the needs of the country's industrialization...The syndrome of being a Great Power and having limitless natural resources intensified a ruthless attitude toward nature."[33] Social movements for nature preservation in the Soviet Union were ignored or ridiculed. ("From whom are we protecting nature, from Soviet man?" asked Lysenkoist philosopher I. I. Prezent.[34]) In suppressing criticism of gigantic state projects, Soviet economic planners denied themselves an important mechanism of social control over technology: professional and public review of organizational failures.

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[31] Ibid., 60-65.

[32] Vorontsov, "Nature Protection and Government in the USSR," 380.

[33] Ibid., 375, 378; see also F. R. Shtil'mark, "The Evolution of Concepts about the Preservation of Nature in Soviet Literature," 429-47, esp. 435; Anton Yu. Struchkov, "Nature Protection as Moral Duty: The Ethical Trend in the Russian Conservation Movement," 413-28, esp. 426; both in *Journal of the History of Biology* (Fall, 1992).

[34] Quoted in Vorontsov, "Nature Protection and Government in the USSR," 383.

Atomic power became the Soviets' next arena for nationalistic technological enterprise. The earliest nuclear reactors in both East and West produced plutonium, an ingredient in nuclear weapons. But while the United States entered the nuclear arms race with a four-year lead, Soviet scientists were the first to adapt a reactor for electric power generation. The experimental Obninsk Atomic Energy Station near Moscow, built under the direction of Igor Kurchatov, the father of the Soviet atomic bomb, yielded its first kilowatt on June 27, 1954, three years before the American prototype light-water reactor at Shippingport. Kurchatov chose the Obninsk reactor's graphite-moderated, water-cooled design -- predecessor to the RBMK -- because it produced more plutonium than other models. Kurchatov's engineers also developed more advanced designs, including a fast breeder reactor and a pressurized-water reactor for use on ships and submarines, but when work on commercial nuclear plants began in 1958 the Obninsk technology prevailed. "It was not because of economic efficiency, safety, or institutional support that the RBMK was later given priority," writes Russian biologist and nuclear power analyst Zhores Medvedev. "It was simply easier for Soviet industry to construct its less sophisticated design...[and] it was the only entirely Soviet system. Other designs would have entailed copying or imitating Western models."[35]

Design changes implemented between 1958 and 1964, when construction began on the first 1000-megawatt RBMK outside Leningrad, added to reactor efficiency at the expense of safety. Like Western pressurized water reactors, the Obninsk reactor featured two separate cooling systems: one to carry heat from the core to a heat exchanger, the other to carry steam to the turbines. The RBMK, however, saved energy by transferring ths heat directly inside the core pressure tubes rather than in a separate steam generator vessel, as in LWRs. As a result the water in the secondary system became radioactive, carrying some 4,000 curies daily to evaporators outside the plant.[36] At low power, the presence of steam inside the reactor also gave rise to a dangerous instability known as the "positive reactivity coefficient" (of which more later). And while Soviet industry lacked the technology to manufacture large steel pressure vessels to enclose the reactor core as in Western LWRs, plant designers had no such excuse for omitting another important safeguard against the escape of radioactivity: a strong external containment structure. In the worst possible accident, it was assumed, only a single pressure tube out of hundreds would rupture. Admonished by government nuclear proponents to demonstrate nuclear power's economic competitiveness, engineers at Moscow's Kurchatov Institute justified each design compromise as a cost-cutting measure.[37]

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[35] Z. Medvedev, 227-230.

But gigantomania -- the tendency to plow ahead with massive engineering projects, minus any understanding of their long-term human and environmental costs -- was also at work in Soviet decisionmaking about reactor safety. Soviet ideology framed technology as the highest form of culture. Large, expensive, highly centralized technologies like nuclear power were seen as the fullest expression of that form. Faith in technology's power fostered an official disregard for its dangers. "The Soviets have had a certain technological hubris. They simply believed it was possible to design things so well that they didn't have to worry about risk," remarked Robert H.

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[36] See note 5 for the definition of curies.

[37] Ibid., 230-240.

Randolph, a student of Soviet science at the National Council for Soviet and Eastern European Research, in a *New York Times* article shortly after the Chernobyl disaster. (The article went on to note that "the same kind of optimism...pervaded the nuclear industry here before Three Mile Island, the chemical industry before the Bhopal disaster and the space establishment before the *Challenger*.")[38]

As nuclear power grew into an icon of the Soviet Union's glorious industrial future, the reality of radiation hazards was never mentioned. Writing in a popular Soviet magazine in 1980, Academician M.A. Styrikovich repeated the standard enthusiasms: "Nuclear power stations are like stars that shine all day long! We shall sow them all over the land. They are perfectly safe!"[39] In 1984 A. M. Petrosyants, president of the State Committee for the Utilization of Atomic Energy, celebrated nuclear energy as one of "the greatest achievements of mankind" and declared that abandoning it would be impossible.[40] Over the three decades preceding the disaster, observed Russian nuclear engineer and Chernobyl investigator Grigori Medvedev, "the ordinary citizen was made to believe that the peaceful atom was virtually a panacea and the ultimate in genuine safety, ecological cleanliness, and reliability."[41]

Good-humored recklessness suffused the Soviet nuclear energy program and was the unfortunate source of its growing electricity output throughout the nineteen-seventies and early nineteen-eighties. By the time of the Chernobyl disaster, crash construction projects had brought the number of operating reactors in the USSR to 43. Fourteen of these were RBMKs. Another 70 reactors were in the construction or planning phases.[42] But aggressive building schedules, an obsession with standardization, poor siting choices, shoddy workmanship, inadequate operator training, and disregard for safety had combined to "convert a risky industry into a terrifying one."[43] Safety shortcuts demonstrated that planners and engineers treated nuclear power no differently from the other technologies that validated the Soviet Union's superpower status: As with the nuclear missiles paraded through Red Square every May Day, the important thing was not just that the technology *worked*, but that it could be *displayed*.[44] The possibility of future harms -- to human health, to the land, to the economy -- figured nowhere in the Party's plans to build 8 to 10 new nuclear plants every year between 1980 and 2000.[45]

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[38] Stuart Diamond, "Chernobyl Rouses Bad Memories, New Fears," *The New York Times* (May 4, 1986) IV:3.

[39] Quoted by G. Medvedev, 2.

[40] Quoted in Josephson, 295.

[41] Grigori Medvedev, *The Truth About Chernobyl*, Evelyn Rossiter, trans. (New York: Basic Books, 1990) 2.

Paul Josephson, an American analyst of Soviet technological history, summarizes the USSR's nuclear program this way: "The long-term historical experience of the Soviet Union with respect to large-scale technologies; the fascination with electrification since the founding of the Soviet state; the self-aggrandizing feeling of national pride and prestige which technologies such as rockets and reactors bring to the USSR, especially in self-conscious competition with the West...All of these factors helped create an environment in which the shortcomings of the Soviet nuclear power program were ignored."[46] The Soviet nuclear establishment admitted its errors only in 1990, a few months before the nation's collapse. Writing in *Soviet Physicist,* the official newspaper of the Kurchatov Atomic Energy Institute, officials commented: "Regarding the RBMK-1000: It's worth reiterating to the public that a similar reactor type will not be constructed in our country, that its selection and significant implementation in the national economy was a mistake."[47]

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[42] Marples, *The Social Impact of the Chernobyl Disaster* , 3.
[43] Graham, 92.
[44] On the politics of technological display, see Michael Smith, "Selling the Moon," in T. Jackson Lears and Richard Fox, eds., *The Culture of Consumption* (New York: Random House, 1986).
[45] Z. Medvedev, 254.
[46] Josephson, 289.

Irregular Experiment, Normal Accident

Accounts of the Chernobyl explosion itself -- and dozens have already been written -- fall into two categories: those emphasizing the numerous errors and safety violations committed by the plant's operators, and those stressing instead the equally numerous design flaws by virtue of which the human errors could culminate in catastrophic failure. The investigators who place blame primarily on the operators, including the authors of the Soviet government's first official report on the accident to the International Atomic Energy Agency, usually interpret this finding as a vindication of the RBMK. "The problem isn't the design," wrote Anatolii Aleksandrov, a member of the Soviet Academy of Sciences, in 1990. "If you're driving a car and turn the wheel in the wrong direction and have an accident, do you say that the engine is at fault? Or its designer? No. Everyone will say that it was the fault of the driver."[48]

Conversely, those who see the accident primarily as an "unanswerable indictment" of the RBMK design tend to let the operators off the hook, portraying them as the victims of a criminally neglectful nuclear bureaucracy.[49] Vladimir Chernousenko, a senior member of the scientific team dispatched to the accident site by the Ukrainian Academy of Sciences, continues the automotive analogy. "To design a reactor with an accident prevention system [like Chernobyl's] is equivalent to designing cars in which, in a moment of need (for example, on a steep descent) the brake pedal becomes an accelerator," Chernousenko writes. "Worse still is to keep quiet about this strange, or rather terrifying characteristic of the brake pedal and then -- after a crash in which the wretched motorist attempted to stop his car using this 'reliable' brake pedal -- to accuse him of not understanding the braking system properly and of being reckless."[50]

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[47] *Soviet Physicist* (Jan. 20, 1990), quoted in Alexander Sich, *The Chornobyl Accident Revisited,* 137.

[48] Quoted in Vladimir Chernousenko, *Chernobyl: Insight from the Inside* (New York: Springer-Verlag, 1991) 71.

In fact, neither viewpoint is adequate. *The worst technological disasters, as we have seen again and again, are the combined result of human error, control mechanisms that fail to account for operator frailty, and plant designs that incorporate high energy reserves and overly complex safety systems.* At Three Mile Island, the operators had both too little and too much information at hand to make correct decisions about the reactor coolant level; moreover, engineers had attempted to buttress the fundamental design flaws of light-water reactors with layers of emergency systems that were themselves failure-prone. At Bhopal, water could only enter the methyl isocyanate storage tank through a combination of operator errors, carelessly designed plumbing, and poor maintenance -- conditions attributable to Union Carbide's absent-minded governance of the plant. The Chernobyl accident was just as much a result of technological imprudence as were the TMI and Bhopal disasters, but as in each of these preceding cases, it took a string of

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[49] Viktor Haynes and Marko Bojcun, *The Chernobyl Disaster: The True Story of a Catastrophe -- An Unanswerable Indictment of Nuclear Power* (London: The Hogarth Press, 1988).

[50] Chernousenko, 76.

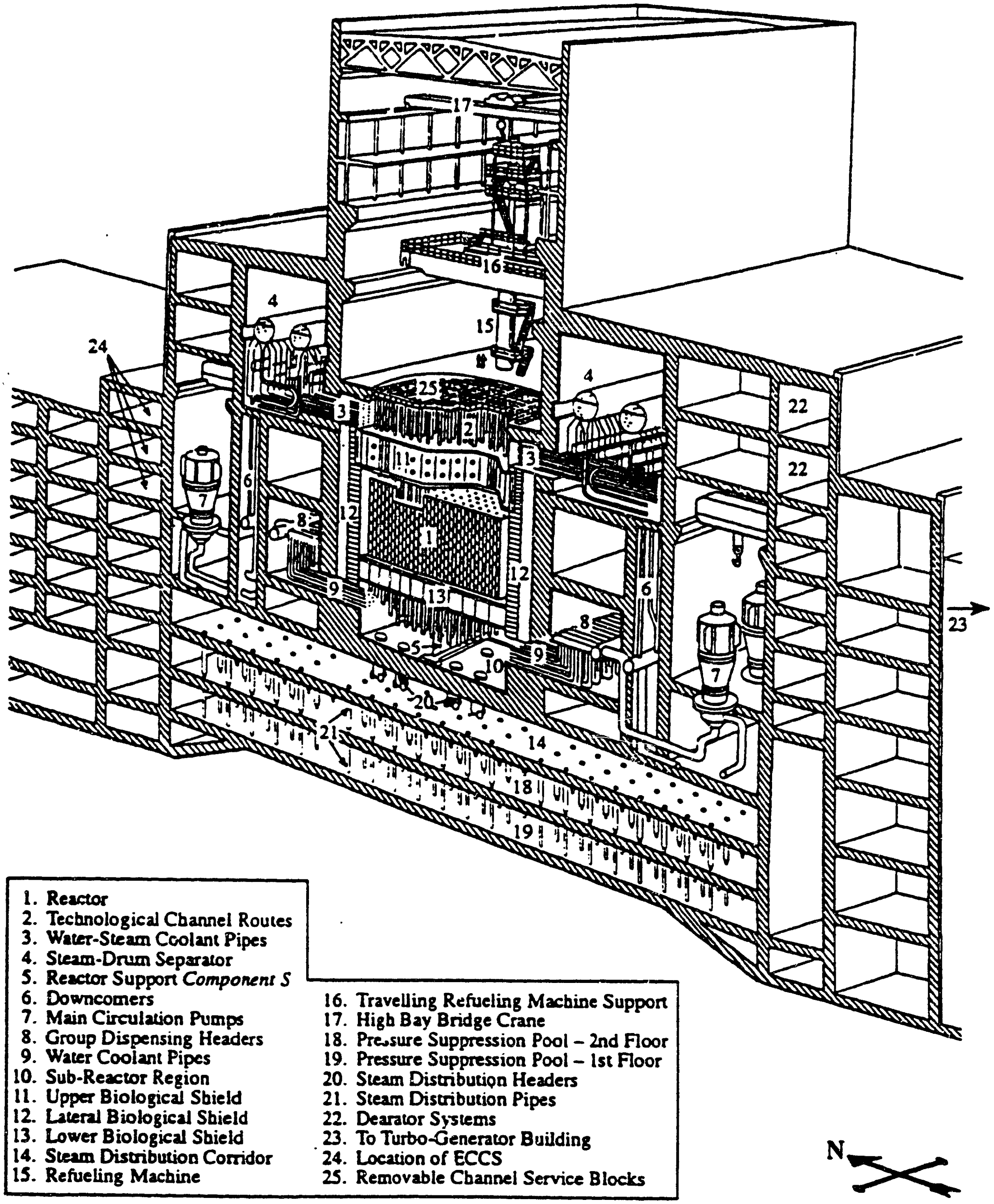
1. Reactor
2. Technological Channel Routes
3. Water-Steam Coolant Pipes
4. Steam-Drum Separator
5. Reactor Support Component S
6. Downcomers
7. Main Circulation Pumps
8. Group Dispensing Headers
9. Water Coolant Pipes
10. Sub-Reactor Region
11. Upper Biological Shield
12. Lateral Biological Shield
13. Lower Biological Shield
14. Steam Distribution Corridor
15. Refueling Machine
16. Travelling Refueling Machine Support
17. High Bay Bridge Crane
18. Pre.sure Suppression Pool – 2nd Floor
19. Pressure Suppression Pool – 1st Floor
20. Steam Distribution Headers
21. Steam Distribution Pipes
22. Dearator Systems
23. To Turbo-Generator Building
24. Location of ECCS
25. Removable Channel Service Blocks
N

Figure 5.1: Sectional View of Chernobyl No. 4 RMBK-1000 Reactor (Source: Alexander R. Sich, The Chornobyl Accident Revisited, 193.)

operator missteps to call forth the hidden pathologies in the system. "The death sentence was implicit...in the very design of the RBMK reactor," writes Grigori Medvedev. "All that was needed was a certain confluence of circumstances making the blast possible. And those circumstances did come together."[51]

Ironically, the "irregular experiment" that led to the explosion of the Chernobyl No. 4 reactor was part of a series of tests intended to reduce the likelihood of a major accident. Soviet nuclear engineers knew that their RBMK reactors, as safe as they supposedly were, suffered from a pesky vulnerability: a gap of 60 to 75 seconds between the failure of a plant's internal electrical system, which powered vital coolant pumps and control rods, and the availability of full power from backup diesel generators. This would be more than enough time for the reactor core -- a huge stack of 2,488 graphite bricks perforated by 1,661 narrow channels for fuel and cooling water -- to overheat and lose coolant. (See Figure 5.1.) The problem was compounded by the fact that RBMKs feature a design peculiarity known as "positive reactivity coefficient": a tendency for the fission reaction to *speed up* uncontrollably when too much of the liquid water in the coolant system flashes to steam, rather than slow down as in Western light-water reactors. To bridge the 75-second power gap and prevent such an occurrence, Chernobyl's operators wanted to see whether a new magnetic field regulator installed inside one of the plant's main turbogenerators would allow the extraction of emergency power from the turbines as they spun down after the cut-off of steam from the reactor.[52]

Similar tests had been conducted previously at Chernobyl and many other nuclear plants, but with one major difference. Safety rules dictated that the emergency core cooling system be ready for activation before such a test could begin. Chernobyl plant director Viktor P. Brukhyanov and chief engineer Nikolai M. Fomin worried, however, that it would be more difficult to repeat the test later if at the moment of switchover from external to internal electrical supply sensors inside the core detected the drop in coolant flow and triggered emergency flooding. They had submitted a proposal to conduct the test with the emergency system *turned off* to the USSR State Committee on Operational Safety in the Nuclear Power Industry, but no reply had yet been received. On April 25, 1986, with the No. 4 reactor scheduled for shutdown and refueling, Fomin directed that the test go forward anyway.

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[51] G. Medvedev, 56.
[52] Z. Medvedev, 8-19.

Between 1:00 a.m. and 1:00 p.m. that day, operators reduced the reactor to 50 percent power. The process was slow because xenon, a neutron-capturing gas which accumulates inside the fuel channels whenever the fission reaction is not held steady, had to be given time to decay and dissipate. At 2:00 p.m., ready to begin the experiment, operators switched off the emergency cooling system.[53] A load dispatcher in Kiev then directed that the reactor continue to feed the national electrical grid, delaying the experiment until 11:00 that evening. (Chernobyl's four reactors together supplied 1.3 percent of the Soviet Union's total electricity, and a vital 45 percent of Ukraine's total nuclear-generated power).[54] The emergency system remained disabled throughout this time. At 11:10 p.m., operators received permission to continue reducing power. The test of the magnetic field regulator was to begin with the generator spinning at an output of between 700 and 1000 thermal megawatts, or about 30 percent of the reactor's maximum.[55]

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[53] *The Truth About Chernobyl*, 32-36.

[54] David Marples, *The Social Impact of the Chernobyl Disaster* (London: MacMillan Academic and Professional Ltd., 1988) 90, 107.

At this point, however, confusion beset the reactor's control room. A new, less-experienced shift of operators came on duty at midnight, led by supervisor Anatoly S. Dyatlov, a deputy chief engineer who had been called "slow-witted, quarrelsome, and difficult" by superiors.[56] The special team of electrical engineers who had been waiting ten hours for permission to begin the test was nearing exhaustion. At some point during the change in shifts, the operators forgot to activate an automatic control system designed to prevent the reactor from dropping below 700 thermal megawatts output; at lower power levels, the fission reaction in an RBMK had proved extremely difficult to control. When the power reduction resumed, therefore, the reactor's control rods moved too far into the core, soaking up neutrons and causing output to plummet to a mere 30 megawatts. Xenon levels inside the fuel channels shot upward correspondingly, and all of the steam in the coolant tubes condensed to liquid water, further poisoning the reaction. Conditions for the test had clearly been ruined. The experiment would have to be put off until the next time the reactor was being powered down for refueling, perhaps in another year.[57]

But Dyatlov thought he saw a way out. Although he had just begun his shift and was not in charge of the experiment, one analyst has suggested that he considered completing the test "a matter of honor."[58] Another speculates that he was caught up in the workplace practice known as *shturm*, the periodic and frantic attempts to meet work quotas before national holidays.[59] If most of the control rods were removed from the reactor, Dyatlov reasoned, power might be restored and the test continued. His subordinates balked at the idea. Regulations required that at least 30 rods remain inserted at all times, and the reactor was already down to 28. In any case, a power increase was prohibited for at least one day after such a precipitous fall to allow time for the extra xenon to decay. But Dyatlov, now shouting and swearing, ordered the senior operator on duty, 26-year-old Leonid Toptunov, to remove most of the remaining control rods anyway. Toptunov remembered thinking, "I might cause a power surge, but if I don't do what I'm told, I'll be fired." (He died of radiation burns soon after this initial statement.)[60]

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[55] For every 3 megawatts of thermal power (MWt) an RBMK reactor produces 1 megawatt of electric power (MWe). Z. Medvedev, 232.

[56] *The Truth About Chernobyl*, 52.

[57] My account of the prelude to the explosion in this and the following three paragraphs relies on the following sources: G.Medvedev, *The Truth About Chernobyl*, 46-57; Z. Medvedev, *The Legacy of Chernobyl*, 24-33; Viktor Haynes & Marko Bojcun, *The Chernobyl Disaster*, 6-10; Victor G. Snell, "The Cause of the Chernobyl Accident," introduction to David Marples, *The Social Impact of the Chernobyl Disaster* , 1-24; John F. Ahearne, "Nuclear Power After Chernobyl," *Science* (8 May, 1987) 673-79; Stuart Diamond, "Moscow Reports A-Plant Workers Ignored Warnings," *The New York Times* (Aug. 16, 1986) A1, A4.

RBMKs very rarely have to be shut down. In normal operation, individual channels are refueled while the reactor is still running. This fact may have lulled Dyatlov, Toptunov and the other operators into the belief that it was safe to disengage more safety mechanisms. According to Alfred Schneider, a professor of nuclear engineering at Georgia Institute of Technology, "There may well have been a false sense of friendship [with the reactor]...because you almost continually work around it when it is running. With that kind of mindset, you are more likely to shut off automatic controls because you think you know the plant so well."[61]

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[58] Valerii Legasov, quoted in Z. Medvedev, *The Legacy of Chernobyl*, 29.

[59] Alexander Sich writes, "The importance of the [May 1st Socialist Labor Day] period for meeting production quotas cannot be overemphasized...The operators were anxious to complete the experiment because they wouldn't have another chance to conduct a similar experiment for over a year (another RBMK station might be ordered to do it instead), and they would lose their holiday bonus for completing the experiment." *The Chornobyl Accident Revisited*, 227.

[60] G. Medvedev, *The Truth About Chernobyl*, 55.

By 1:00 a.m., April 26, Toptunov had coaxed the reactor back up to an output of 200 thermal megawatts. Hoping to increase steam pressure inside the reactor and push the power further upward, he switched on two additional coolant pumps, but the extra water flowing into the core only lowered the reactor temperature. More control rods came out to compensate. With steam volume now falling toward levels that would have triggered an automatic reactor shutdown, Toptunov disengaged the emergency sensors inside the steam drums. As Canadian nuclear scientist Victor Snell would later write, all of this was "rather like driving a car with the accelerator floored and the brakes on -- it was abnormal and unstable."[62]

At 1:21 a.m, the operators choked off the reactor's water supply in a final attempt to force the temperature back up. A few control rods fell into the core automatically, but even so there were now only six to eight rods in place. At 1:23 a.m., while the control room computer disgorged printouts calling for an immediate shutdown, the reactor momentarily stabilized at 12 percent of maximum power. Although the turbogenerator test would be useless at this low power level, Dyatlov ordered that steam flow to the turbines be cut off. But first, hoping for a chance to repeat the experiment if necessary, he told Toptunov to disable another emergency mechanism, one which would have detected the disconnection of the turbine and shut down the reactor. It was the reactor crew's sixth and final mistake.[63]

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[61] Stuart Diamond, "U.S. Experts Say Chernobyl's Design Made Workers' Risk-Taking Worse," *The New York Times* (Aug. 18, 1986) A6.

[62] Snell, in Marples, *Social Impact*, 15. Hans Blix, Director General of the International Atomic Energy Agency, has offered a similar comment: "Operating the RBMK reactors in the ex-Soviet Union is like driving a 1928 Ford...safe only with very special handling." Ariane Sains, "Blix: RBMKs Can't Meet Safety Norms, But Nuclear is Necessary," *Nucleonics Week* (Sep. 24, 1992) 14. That the comparison between cars and nuclear power plants is so often made underscores the human need to frame complex hazards in terms of familiar ones, and may also indicate the extent to which the automobile has become the dominant technological icon of our time.

Electricity from the gradually slowing turbine was now feeding four of the reactor's eight main pumps. As the power dwindled, so did the volume of water flowing through the reactor. Moving more slowly over the hot fuel, the water began to turn to steam. Now the positive reactivity coefficient came into play: a decrease in the amount of liquid water inside the reactor meant that fewer neutrons were being captured in their post-fission flights. They barrelled instead through the graphite blocks, where they were sufficiently slowed to cause more fissions in the fuel rods. This in turn released heat that boiled more water. In a single second this self-reinforcing cycle pushed the reactor from 200 to an incredible 32,000 thermal megawatts, 100 times full power. The "brakes" had been unalterably released.[64]

At 1:23:40 Toptunov noticed the precipitous power buildup and pushed an emergency button to lower all the control rods, but two final design flaws now sealed the reactor's fate. In RBMKs it took 15 to 24 seconds for the control rods to drop all the way into the core, an eternity compared to the pace at which energy was gathering inside the reactor. And while the rods themselves were constructed of a neutron-absorbant material, their tips -- the first part to enter the reactor -- were made of graphite, which only slows neutrons to fission-ready speed. During the first few seconds of control rod insertion, then, the effect was actually to *increase* the reactor's power rather than to decrease it. Within four seconds the reactor's output jumped from 100 to 470 times maximum, at which point the control rods overheated and turned to powder. The fuel channels ruptured and caused rapid boiling of the coolant water, cracking the pressure tubes. A massive steam explosion ensued. The flimsy containment structure around the graphite pile burst, and the 1,000-ton concrete shield atop the reactor flew into the air like a tossed coin. Much of the reactor building was destroyed in the explosion. Burning fragments of uranium fuel and graphite soared skyward, landing in a three-kilometer radius around the plant and starting more than two dozen fires. Radioactive fuel decay products like iodine-131, cesium-137, zirconium-95 and ruthenium-103 began pouring into the atmosphere.

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[63] The six major errors were as follows: 1) Disabling the emergency core cooling system, 2) neglecting to activate automatic controls to prevent power from dipping below 700 thermal megawatts, 3) removing more control rods to counteract for the subsequent power loss, 4) disengaging the steam drums' pressure-sensitive emergency shutdown system, 5) interrupting coolant flow through the core, and 6) disengaging the turbogenerator's emergency shutdown system. Investigators have called this series of missteps "incredible" and "unforeseeable," but each decision was seemingly dictated by the logic of the moment.

[64] This phenomenon cannot occur inside a Western-style reactor, where circulating water acts as both moderator and coolant and the fission reaction ceases if coolant is lost.

It was not history's worst nuclear accident -- the USSR had already attained that distinction when a waste tank exploded at a nuclear weapons factory at Kyshtym in the Ural Mountains in 1957, spreading long-lived radionuclides over 2,000 square kilometers[65] -- but it was one whose pan-Soviet and even international dimensions would be impossible to hide. According to Soviet nuclear industry economist Yuri Koryakin, the costs from lost electricity production and contaminated farmland alone would reach 170 billion to 215 billion rubles by the year 2000, equivalent to between $283 billion and $358 billion at 1990 exchange rates. (Koryakin's work suggested that the Soviet Union would have been better off if it had never built nuclear power plants, since the net savings from their use over more costly coal-burning plants from 1954 to 1990 was only 10 to 50 billion rubles.)[66] With the Soviet economy already in a tailspin, these crushing costs would quicken the depletion of government coffers. And the Chernobyl operators' foolish mistakes, set within the context of a deeply flawed technological system and an irresponsible nuclear bureaucracy, would soon come to symbolize the cultural and political depletion of the Soviet state itself.

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[65] Z. Medvedev, *The Legacy of Chernobyl*, 279-86.

[66] Richard L. Hudson, "Cost of Chernobyl Nuclear Disaster Soars in New Study; 1986 Reactor Accident Dwarfs Other Soviet Peacetime Catastrophes," *The Wall Street Journal* (March 29, 1990) A8.

An Assault on Health and Nature

The explosion's immediate aftermath and the frantic attempts to snuff out the reactor's "crimson incandescence" have already been described. The emergency caught the Ukrainian and central Soviet governments unprepared, and while some 500,000 people were eventually evacuated from the 30-kilometer-radius "exclusion zone" around the plant and from nearby cities, including thousands of children who were moved from the Ukrainian capitol of Kiev, the official response to the accident was initially one of sloth and denial. The majority of Party and government authorities, David Marples writes, "acted as though nothing were happening."[67] Beyond government mismanagement of the emergency and of the nuclear industry itself, however, it was the disaster's threat to human health and the environment that angered the Soviet public -- especially in the areas of Ukraine, western Russia, and Byelorussia (now Belarus) where radioactive fallout was heaviest. "When historians finally conduct an autopsy on the Soviet Union and Soviet Communism," Sovietologist Murray Feshbach and journalist Alfred Friendly have written, "they may reach the verdict of death by ecocide....No other great industrial civilization so systematically and so long poisoned its air, water, and people."[68] As the most vivid, frightening, and well-publicized of the USSR's environmental blunders, Chernobyl provoked a long-overdue public outcry against this ongoing assault on health and nature, with regime-toppling results.

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[67] David R. Marples, *The Social Impact of the Chernobyl Disaster* (London: MacMillan Academic and Professional Limited, 1988) 29.

Questions of blame and responsibility guaranteed that "Chernobylogy," the scientific and biomedical study of the disaster, would be a highly politicized affair from the beginning. Even eight years afterward, the likely extent of the deaths, injuries, radioactive contamination, and epidemic disease caused by the disaster remains a matter of intense disagreement.[69] As Zhores Medvedev explains, "People who are opposed to nuclear power tend to make the highest possible estimates [of the damage to health], while those in favor of it opt for the lowest possible figures."[70] Felicity Barringer, Moscow correspondent for the *New York Times* when the disaster struck, puts it more bluntly: "With a thousand different versions of the truth in the newspapers and official statements, people believe whatever story best fits their fears."[71]

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[68] Murray Feschbach and Alfred Friendly, Jr., *Ecocide in the USSR: Health and Nature Under Siege* (New York: Basic Books, 1992) 1.

[69] The dispute entered a new phase in 1994 with the publicity surrounding the data presented in Alexander R. Sich's MIT nuclear engineering dissertation, *The Chornobyl Accident Revisited: Source Term Analysis and Reconstruction of Events During the Active Phase* (Jan., 1994). (Sich is an ethnic Ukrainian and uses the Ukrainian spelling "Chornobyl" rather than the Russian spelling "Chernobyl.") The most important new finding in Sich's work is that almost none of the quenching materials dumped from helicopters during the attempt to douse the burning reactor actually entered the core area. As a result, Sich asserts, the core materials that remained inside the reactor after the explosion burned uncontrollably for approximately nine days, releasing four to five times more radionuclides into the atmosphere than previously claimed by Soviet and Ukrainian nuclear scientists. Sich's dissertation also presents an extremely detailed account of the accident's progress, bringing together data from a number of disparate sources (including many I have used here) on the explosion and extent and location of the radioactive fallout it caused. Sich's work has shed needed light on several poorly-understood aspects of the disaster, but Sich -- who has publicly attacked Chernobyl scientist Vladimir Chernousenko as a fraud -- cannot himself be regarded as a dispassionate observer of the accident and its consequences. His conclusions must be regarded with the same caution demanded when approaching all treatments of this highly politicized event.

[70] Z. Medvedev, *The Legacy of Chernobyl*, 166.

[71] Felicity Barringer, "Chernobyl: Five Years Later, The Danger Persists," *The New York Times*

The true global magnitude of the Chernobyl disaster is probably impossible to determine. In this as in many other health and environmental controversies, complete and "objective" data are simply unavailable. But the data that *are* available are the only ones that can affect politics, and they are worth reviewing if for that reason alone.

For the first four years after the tragedy, the official death toll stood at 31. According to a 1987 *Novosti* press agency report, two men were killed in the original explosion, and another 29, mostly firefighters, absorbed between 200 and 1,600 rem per person and died of radiation sickness within months.[72] In 1990 the government announced that between 250 and 350 additional deaths had occurred among the 180,000 "liquidators": workers, mainly young soldiers, who had been brought in to decontaminate the most heavily irradiated parts of the reactor building and the surrounding zone. But scientists and others critical of the government's role in the disaster, including many who had taken part in the cleanup effort, ridiculed even this revised estimate. In their book *Ecocide in the USSR*, Feshbach and Friendly calculated on the basis of measured radiation levels and the known effects of such levels on humans that approximately 4,000 liquidators must have died prematurely by 1991.[73] Yurii Shcherbak, a Ukrainian physician who became a leader of the republic's environmental movement after the disaster, put the figure at 5,000.[74] Ukrainian health officials said in 1992 that between 6,000

Magazine (April 14, 1991) 28-39, 74.

[72] "Rem," for *rad-equivalant-man*, is a weighted measure of ionizing radiation absorbed per unit mass of human tissue; 100 rem are usually enough to produce clinical signs of radiation sickness. An individual's exposure to natural background radiation typically amounts to less than 0.5 rem per year. Marples, *The Social Impact*, 33-34.

[73] Feshbach and Friendly, 146.

[74] David R. Marples, "Revelations of a Chernobyl Insider," *Bulletin of the Atomic Scientists* (Dec., 1990) 16-21.

and 8,000 deaths had occurred among the liquidators.[75] Vladimir Chernousenko, the Ukrainian science team member who has spoken widely against the continued use of RBMKs, stated in 1991 that 7,000 liquidators had died, and in 1993 he contended that the number had risen to 15,000.[76] But others believe that many of these figures have been exaggerated. Alexander Sich, who spent 18 months inside the exclusion zone gathering data for his 1994 MIT doctoral dissertation in nuclear engineering, points out that it would be difficult for the state to conceal thousands of new graves. Sich cites an assertion by Ilya Likhtaroyov, head of the Department of Dosimetry and Radiation Hygiene at the Ukrainian Ministry of Health, that the expected mortality in an average population over the years since the disaster "would not differ greatly" from the actual number of deaths among the liquidators.[77] This argument has been contested, but Sich's main point is that the exact death toll is irrelevant to the question of the RBMK's safety. "Is not one victim enough -- let alone the thirty or more already undisputed -- to condemn a reactor design long known to be deficient?" he asks.[78]

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[75] Alexander R. Sich, *The Chornobyl Accident Revisited*, 128.

[76] Author's notes from Chernousenko's remarks at the Technology and Culture Seminar, Building 25, Massachusetts Institute of Technology, Oct. 26, 1993.

[77] Likhtaroyov's statement is from Mark Hibbs and Ann Maclachlan, "Ukainian Expert Details Doses and Follow-Up from Chernobyl," *Nucleonics Week* (May 7, 1992) 6. This assertion does not appear to coincide, however, with known mortality rates in the Soviet Union during the nineteen-eighties. Mortality data for the Soviet Union in the years 1986-1989 would lead one to expect a "background level" of between 1,764 and 1,818 deaths each year among a randomly selected group of 180,000 people (the size of the population of liquidators), for a total of between 8,820 and 9,090 deaths in the five years from 1986 to 1991. But normal mortality rates would naturally be much lower among the younger age groups represented by the liquidators, who were mostly young military recruits. (See Table A.3 in Feschbach and Friendly, 273.) Dr. Ira Helfand, an emergency-room physician at Cooley Dickinson Hospital in Northampton, Massachusetts, and treasurer of Physicians for Social Responsibility, insists that the death rate among the population aged 18-35 in the former Soviet Union is much lower than 1 in 100 per year, adding that if 7,000 people have died among the 180,000 liquidators "then clearly some mechanism is at work" to cause this high mortality rate. (Author's notes from Helfand's remarks at the Technology and Culture Seminar, Building 25, Massachusetts Institute of Technology, Oct. 26, 1993.) See also Kenneth Lichtenstein and Ira Helfand, "Radiation and Health: Nuclear Weapons and Nuclear Power," in Eric Chivan, M.D., et al., eds., *Critical Condition: Human Health and the Environment, A Report by Physicians for Social Responsibility* (Cambridge, Mass.: MIT Press, 1993) 93-122.

Estimates of the total amount of radioactive material emitted during the explosion and subsequent 10-day fire also vary widely. The Chernobyl No. 4 reactor had been running continuously for more than two years before the explosion, and some three-quarters of the original uranium fuel had decayed into other radioactive isotopes with longer or shorter half-lives. The total radioactive inventory of the reactor was near 1,200 MCi. Between 55 and 400 MCi is believed to have escaped -- either way, a vast cloud of radioactive particles far exceeding the fallout at Hiroshima.[79] According to one study, 36 MCi of iodine-131 entered the atmosphere, sixty percent of the core inventory of that isotope, along with 1.3 MCi of long-lived cesium-134 and 2.4 MCi of cesium-137.[80] Sich found that some 48.1 MCi of cesium-136, with a half-life of 13 days, were also released.[81] At least 20 MCi of fallout landed in the 30-kilometer zone around the reactor. According to Soviet data, a total of about 240 MCi of long-lived isotopes like cesium-137, strontium-90, and plutonium-241 were scattered across the Soviet Union, and an undetermined amount -- perhaps equally large -- drifted elsewhere around the globe.[82] Changing winds carried fallout over Scandinavia, Great Britain, and central and southern Europe, and eventually even to Japan and North America.[83]

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[78] Alexander R. Sich, *The Chornobyl Accident Revisited*, 44.

[79] Z. Medvedev, 74; Haynes and Bojcun, 20-21; Barringer, "Chernobyl: Five Years Later, The Danger Persists," 28. Sich estimates that at least 200 Mci of radionuclides were released, four times the Soviets' initial estimate in their Vienna report; in terms of mass, this would be 200 times the fallout from the atomic explosion at Hiroshima. Sich, *The Chornobyl Accident Revisited*, 392, 417.

[80] P. H. Gudiksen, et al., "Chernobyl Source Term Atmospheric Dispersion and Dose Estimation," *Health Physics* (Nov., 1989) 704; cited in Allan S. Krass, "Consequences of the Chernobyl Accident," *Institute for Resource and Security Studies Working Paper No. 5* (Cambridge, Mass., Dec. 1991) 5; see Table 2. Sich's data on these radioisotopes are similar; he estimates the release of iodine-131 at 31.1 MCi, of cesium-134 at 1.3 Mci, of cesium-137 at 2 Mci. *The Chornobyl Accident Revisited*, 394.

[81] Ibid.

[82] Calculated using data from the 1986 Soviet INSAG-1 report to the IAEA. Only elements with a half-life over 500 days are included. See Table 3.1 in Z. Medvedev, 78.

Exactly where the radionuclides fell to earth, and in what concentrations, is fairly well understood. In the Soviet republics some 25,000 square kilometers of land, home to 824,000 people, were contaminated with at least 5 Ci per square kilometer. Areas where millions more resided, including parts of Poland, Austria, Romania, Yugoslavia, Germany, Switzerland, Finland, Sweden, and Norway, received between 0.27 and 2.7 Ci per square kilometer.[84] But scientists' inability to translate these figures into reliable estimates of individual radiation doses gives broad license to interpreters of the fallout's ultimate effects on health. The International Atomic Energy Commission puts the lifetime dose for the 824,000 residents of the worst-contaminated areas at 8 to 16 rem, while the Soviet government's projections are two to three times as high. Estimates of the population dose for the entire Northern Hemisphere also vary by a factor of two: a United Nations study says the equivalent of 6 million people will receive a lifetime dose of 10 rem, while the U.S. Department of Energy says 12 million people will receive this dose.[85]

Over decades, these exposures will add a large number of cancer deaths to the toll already incurred from radiation sickness, but just *how* large is highly disputed. By 1990, the incidence of thyroid cancer in the worst-affected areas of Ukraine, Belarus, and western Russia had already jumped to 5-10

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[83] Lynn R. Anspaugh, et al., "The Global Impact of the Chernobyl Reactor Accident," *Science* (Dec. 16, 1988) 1513-1519.

[84] These figures are from the International Atomic Energy Agency, *The International Chernobyl Project: An Overview* (Vienna, IAEA, 1991) 55; quoted in Krass, 14.

[85] This is the same as saying that 60 to 120 million people will receive a lifetime dose of one rem, or that between 600 million and 1.2 billion will receive a tenth of a rem. Total population doses are calculated in person-Sieverts, where one Sievert = 100 rem. See Krass, 15.

Table 5.1: Predicted Lifetime Cancer Fatalities From Chernobyl Fallout and Natural Background Radiation[86]

Population Exposed	**Number Exposed**	**Excess Cancer Deaths (Chernobyl)**	**Expected Cancer Deaths (Natural Causes)**	**Percent Increase**
Acute Exposure	4,000	640	800	80%
Serious Exposure	50,000	2,000	10,000	20%
Exclusion Zone Inhabitants	135,000	1,200	27,000	4.4%
Cesium Deposition > 5 Ci/km^2	824,000	5,300-26,400	165,000	3.2%-16%
Liquidators	600,000	2,000-6,000	40,000-120,000	5%
Northern Hemisphere	3 billion	48,000-96,000	600,000,000	0.008%-0.016%
Natural Background Radiation	3 billion	17,000,000	600,000,000	2.8%

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[86] Adapted from Table 4 in Krass, p. 21.

times the normal rate, and childhood leukemia cases had quadrupled.[87] The environmentalist and anti-nuclear group Greenpeace projects that between 280,000 and 500,000 excess cancer deaths will ultimately occur worldwide as a result of the catastrophe, while the European Organization for Economic Cooperation and Development (OECD) contends that the scientific uncertainties are so great that no projection should be made at all. Between these extremes are models calling for increased cancer death rates of anywhere between 0.008 percent (for the entire Northern Hemisphere) and 80 percent (for the 4,000 most acutely exposed liquidators). These predictions are summarized in Table 5.1.

Through careful, long-term epidemiological studies it might be possible to confirm predictions of extra cancer deaths among the first four groups listed in the table. Globally, however, Chernobyl-related cancers will be indistinguishable from those caused by natural background radiation and other environmental insults. "It will almost certainly never be possible unambiguously to attribute to Chernobyl fallout any particular cancer or cluster of cancers outside the immediate vicinity of the plant," observes physicist and policy analyst Allan Krass. He adds, "This makes the question of assigning liability for compensation and damages highly problematic."[88]

Lay people attempting to trace their own illnesses to specific industrial toxins inevitably face this barrier of scientific uncertainty, which government or industry officials have often used as a convenient rationale for denying citizens' claims. In Woburn, Massachusetts, for example, state and federal health officials downplayed the possibility of an association between high childhood leukemia rates and trichloroethylene contamination of municipal well-water until townspeople themselves gathered the epidemiological data to demonstrate such a link.[89] The need for citizens to become "environmental detectives" or "lay epidemiologists" in order to substantiate their own victimization reflects the fundamental political reality that technical and scientific expertise is often monopolized by the state or by private industry; we have already seen how swiftly experts dismissed the fears of people living near Three Mile Island during the meltdown and the worries of chemical-plant neighbors after Bhopal. Rarely, however, has the *source* of an industrial poison been as obvious and indisputable as at Chernobyl. Hundreds of people, if not thousands, died within years after the accident, and millions more learned that their land was no longer safe to farm, their food no longer safe to eat, their villages no longer safe to live in. Public fear and anger over the possibility of a repetition of Chernobyl at any of the USSR's 42 other nuclear reactors gradually coalesced into the most widespread and effective protest movement in Soviet history.

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[87] Felicity Barringer, "Four Years Later, Soviets Reveal Wider Scope to Chernobyl Horror," *The New York Times* (April 28, 1990) A1, A4.
[88] Krass, 22.

Soviet Nuclear Power After Chernobyl

One Western scientist joked a year after the disaster that the only nuclear power program not set back by Chernobyl was the Soviet Union's.[90] In the United States and Western Europe, the catastrophe reinforced existing anti-nuclear sentiment and sent engineers scrambling to check their plants' design characteristics against those of the RBMK. Critics quickly pointed out that five U.S. reactors lacked concrete-and-steel containment domes and that two used graphite to moderate the fission reaction. Massachusetts Representative Edward Markey said Chernobyl should force "a re-examination of nuclear power in this country, much like the soul-searching that followed Three Mile Island."[91] The Soviet government, meanwhile, remained outwardly determined to continue the expansion of nuclear power, an important element of Mikhail Gorbachev's ambitious economic reform program. Gorbachev admitted in his first televised address after the disaster that "the questions of reliability and safety of equipment, the questions of discipline, order, and organization [now] assume priority importance," but Kremlin plans still called for a doubling of nuclear power, from 11 percent of the total Soviet energy output to 22 percent, by 1991.[92]

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[89] See Phil Brown and Edwin Mikkelsen, *No Safe Place: Toxic Waste, Leukemia, and Community Action* (Berkeley: University of California Press, 1990).

[90] As reported by Bill Keller, "Public Mistrust Curbs Soviet Nuclear Power Efforts," *The New York Times* (October 13, 1988) A1, A10.

Official portrayals of the accident seemed calculated to belittle its significance for Soviet nuclear policy. A Politburo statement released in July, 1986, announced the formation of a new Ministry of Atomic Power Engineering to oversee the industry and added that several Chernobyl plant officials, including Bryukhanov, would be expelled from the Communist Party. "What was missing from the report," noted *New York Times* Moscow correspondent Serge Schmemann, "was any suggestion that the Kremlin's own insistent demands for rapid expansion of nuclear energy could have contributed to the accident. The entire responsibility was apportioned among the power plant's officials and Government ministries, and no blame fell on party officials or party policy."[93] Valerii Legasov's report to the IAEA a month later attributed the accident to "an extremely improbable combination of procedure violations" and faulted RBMK designers only for failing to foresee the "impossible."[94]

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[91] One Hanford, Washington, plant used graphite *and* lacked containment. Fred Kaplan, "Six U.S. Facilities Have Similarities to Soviet Plant," *The Boston Globe* (April 30, 1986) 3.

[92] Associated Press, "Excerpts from Gorbachev's Speech on Chernobyl Accident," *The New York Times* (May 15, 1986) A10; Z. Medvedev, 292.

[93] Serge Schmemann, "Chernobyl Answers: New Questions," *The New York Times* (July 21, 1986)A3.

This outward optimism masked a certain amount of alarm among Party and industry officials. After the explosion all of the Soviet Union's RBMKs were shut down temporarily for safety checks. By implementing a series of organizational changes and technical fixes at existing plants, including a mechanism for quicker insertion of the control rods, nuclear engineers and bureaucrats hoped to ensure -- at least on paper -- that an accident like the one at Chernobyl could not happen again. Debate within the scientific community over the risks of nuclear power, especially after Legasov's suicide, had begun to foster a new level of realism about reactor safety. But none of these changes proceeded fast enough or reached deeply enough to satisfy the Soviet Union's growing number of critics of nuclear power. "What we have is an ideally functioning system of collective irresponsibility," one Russian writer commented in 1990. Safety, he asserted, could only can be restored through "a fundamental reform of our socioeconomic and political life."[95]

Reform started slowly. Aside from a few timid complaints, including letters published in *Pravda* from Chernobyl evacuees who claimed officials had treated them poorly, public animosity toward the Soviet nuclear establishment simmered quietly for more than a year after the accident.[96] "Many former Soviet citizens describe this first year as a period of shock, during which they first began to grapple with the notion that the central government might be neither competent nor as credible as previously believed," relates Jane Dawson.[97] Still wary about the government's true commitment to *glasnost*, most critics restricted themselves to oblique cynicism. "We are being assured that the situation is absolutely normal and well-nigh better than it was before the accident," one Ukrainian writer observed on a Moscow television program. "Is there really no room for improvement? Let's blow up one more unit to make the situation really splendid!"[98]

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[94] Tass Press Agency, "Excerpts From the Report on Chernobyl and News Conference in Moscow," *The New York Times* (Aug. 22, 1986) A4; Stuart Diamond, "Moscow Now Sees Chernobyl's Peril Lasting For Years; Big Area Stricken," *The New York Times* (Aug. 22, 1986) A1, A4.

[95] Boris Kurkin, "Systems of Nuclear Irresponsibility," *Literaturnaya Rossiya* (June 8, 1990), quoted in William C. Potter, "The effects of Chernobyl on Soviet decision-making for nuclear safety," *Impact of Science on Society* (no. 163) 264.

[96] United Press International, "Chernobyl Evacuees Complain to Pravda," *The New York Times* (Aug. 19, 1986) A12.

In 1987, however, popular opposition to the Soviet nuclear program began to come into the open. In August the Kiev newspaper of the Ukrainian Writers' Union, *Literaturna Ukraina*, published a groundbreaking critique of plans to build a new atomic energy station near Chyhyryn, on the Kremenchuk reservoir southeast of the city. The proposed plant would do "irreparable harm" to the local environment and would threaten the drinking-water supply of all the cities downstream, the writers asserted. "Is it possible that the Chernobyl tragedy taught us nothing?" they asked.[99] Although not yet coordinated into a widespread anti-nuclear movement, protests were beginning to hinder work at several nuclear construction sites. A nuclear power and heat-generating facility planned for Kiev was scrapped in October, 1987, and in November Valerii Legasov told a German magazine that plants in Odessa and Minsk were also under fire.

In December 1987, during a conference in Kiev entitled "Scientific-Technical Progress and Morality," physician Yurii Shcherbak and other members of the Ukrainian Writers' Union formed an unofficial group called Zelenyi Svit (Green World) to press for the closure of the Chernobyl plant and a freeze on all nuclear construction in Ukraine. The group hoped to tie together the small environmental clubs forming all across Ukraine to oppose nuclear projects, but with hardliner V. Shcherbitsky still in charge of the Ukrainian Communist Party, it could take little action as yet. Citizens' organizations could not legally exist outside the Party structure in Ukraine. Street activism of all kinds was still forbidden; fifty people were arrested in Kiev for unfurling anti-nuclear banners on the second anniversary of the accident. But Zelenyi Svit functioned nonetheless as the center of a growing, informal network of nuclear opponents.

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[97] Jane I. Dawson, "Anti-Nuclear Activism in the Former USSR: A Surrogate for Nationalism?" in Essig and Sachs, eds., *Activism and Apathy in the Former USSR* (Westview Press, forthcoming) provided courtesy of the author.

[98] from *Moscow News* (July 12, 1987) 11; quoted in Marples, *The Social Impact of the Chernobyl Disaster*, 263.

[99] quoted in Marples, *The Social Impact of the Chernobyl Disaster*, 263-67.

1988 was the year, notes Dawson, when "anti-nuclear movements emerged around literally every nuclear station under construction or in operation in Ukraine" [there were 29].[100] Dawson's research took her to the rural Khmelnitsky oblast, where a large four-reactor complex was being built in the village of Netishin. In 1987 residents concerned about the Chernobyl accident had tried to circulate petitions opposing the Netishin plant, but officials had simply confiscated the petitions as illegal. Now the dissent was becoming more difficult to stem. Drawing on interviews with local anti-nuclear activists, Dawson writes that "The key factor in mobilizing [Khmelnitsky] society against the nuclear power station was the flood of information that suddenly deluged the population after January of 1988 [when officials lifted the requirement that all articles pertaining to nuclear power be cleared with military censors]...People who had not even thought about the new nuclear power station in Netishin and the government's plans to expand it suddenly learned that the station had experienced major construction problems, numerous small accidents, and unscheduled shutdowns of its single completed reactor, and was possibly defectively constructed...In addition...the residents of Khmelnitsky also began to learn of the true magnitude of the Chernobyl disaster."[101]

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[100] "These movements might best be compared to the NIMBY movements observed in the West," she suggests. Dawson, "Anti-Nuclear Activism in the Former USSR: A Surrogate for Nationalism?" 20; Sich, *The Chornobyl Accident Revisited,* 441-42.

In the nearby town of Shepetovka, Dawson relates, local residents organized a rebuttal to the "educational" sessions being led by nuclear specialists at area factories and club meetings:

> On March 15, 1989, the nuclear specialists found their plans for a quiet educational session at the Railroad Workers' Club in Shepetovka quite rudely interrupted. Rather than sitting quietly and accepting the specialists' claims, a handful of local opponents began asking questions and accusing the specialists of falsifying information. Soon other local residents began to sit up and interject their own questions and doubts into the discussion, and within no time the specialists had lost control of the session. They were shocked by their reception, and eventually called in the Communist Party First Secretary of the region...to bring the meeting back under control.[102]

After the session, residents organized the Committee to Halt Construction and Close Khmelnitsky Atomic Energy Station and declared themselves a chapter of Zelenyi Svit. Residents in Netishin and the town of Ostrog followed suit, and the groups held several public rallies to attract support among workers' collectives in the area. "The mass meetings held during the spring of 1989 in Shepetovka and Netishin came as quite a shock to the residents of this quiet oblast," Dawson observes. "Many people recall these meetings as the beginning of the politicization of the region. People who had never before considered opposing state policy in any way began to recognize the possibility of participating in this movement and perhaps shaping state policy."[103] Individuals were teaching themselves concepts of political participation that had always been denied them by Party rule, and they were organizing in groups to nourish their newfound freedoms. These two simple yet courageous acts -- repeated in a thousand cities and villages -- slowly began to loosen the Communist state's once-firm commitment to nuclear energy.

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[101] Dawson, *Social Mobilization in Post-Leninist Societies: The Rise and Fall of the Anti-Nuclear Power Movement in the USSR* , 193.

[102] Ibid., 196.

The official press in Ukraine and Russia could hardly help acknowledging nuclear power's increasing travails. In January 1988 the newspaper *Komsomolskaya Pravda* revealed that officials in Krasnodar, near the Black Sea, had acceded to a flood of letters demanding the abandonment of a plant there. "Before Chernobyl, to have a nuclear power plant was profitable -- and prestigious," the newspaper said. "But then the entire world started talking about Chernobyl." Nuclear power planners rightly feared that Krasnodar would be the first in a "chain reaction" of plant cancellations due to public opposition.[104] In April the Communist Party newspaper *Pravda* charged Kombinat, the organization responsible for managing the Chernobyl cleanup, with nepotism, lax discipline, and neglect of safety measures. "The leadership of Kombinat has not learned a lesson from the past. It is as though there had been no accident," the newspaper said.[105]

The newspaper *Pravda Ukrainy*, in answer to rising public concern, began printing weekly reports on radiation levels in Kiev and outlying cities.[106] A few weeks after Legasov hanged himself, *Pravda* printed his recrimination-filled memoir. Criticism of nuclear power may have directly conflicted with Gorbachev's economic goals, but *glasnost* and *perestroika* were allowing private complaint to blossom slowly into full-blown public debate. "While Chernobyl provided the population with an intimate awareness of the dangers of nuclear power facilities, *perestroika* provided the opportunity and resources for independent actors to publicize their concerns and mobilize the population against the government's program," writes Dawson.[107]

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[103] Ibid., 202.

[104] Bill Keller, "Soviet Scraps a New Atomic Plant In Face of Protest Over Chernobyl," *The New York Times* (January 28, 1988) A1, A9.

[105] Bill Keller, "Chernobyl Plant Being Mismanagaed, Pravda Charges," *The New York Times* (April 25, 1988) A1, A6.

[106] Felicity Barringer, "Fear of Chernobyl Radiation Lingers for the People of Kiev," *The New York Times* (May 23, 1988) A1, A7.

Controversy was fiercest at Ignalina, Lithuania. Already home to two giant 1,500-megawatt RBMKs, Ignalina was slated to be the site of yet a third reactor. In September 1987 six thousand protestors encircled the plant, demanding that the third reactor be permanently abandoned and that the existing two be opened for international inspection. Protest organizers condemned the construction project as a policy of "genocide" against the Lithuanian people.[108] Ignalina plant director Anatoly Khromenko predicted that the demonstrators would have their way, lamenting that "everything we do now in nuclear power is affected by Chernobyl." Work at Ignalina was suspended in August, 1988. By October of that year, five nuclear stations had been canceled outright and work had been suspended at several more.[109]

Party organizations in many areas of Ukraine, while rigidly dismissive of anti-nuclear groups' demands in 1987 and 1988, began to soften their stance in 1989. Shcherbitsky was ousted in September of that year and local anti-nuclear groups now encountered no official resistance when they circulated petitions, held mass rallies, or blockaded the gates of nuclear stations.[110]

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[107] Dawson, "Anti-Nuclear Activism in the Former USSR: A Surrogate for Nationalism?" 2.
[108] Ibid., 16.
[109] Bill Keller, "Public Mistrust Curbs Soviet Nuclear Power Efforts," *The New York Times* (Oct. 13, 1988) A1, A10.
[110] Dawson, "Anti-Nuclear Activism in the Former USSR: A Surrogate for Nationalism?" 21-22.

Recognizing the extent of the popular discontent generated by the Chernobyl accident -- and perhaps fearful for their own health and safety -- Party officials began to echo Zelenyi Svit's call for restrictions on nuclear power construction. In Khmelnitsky, for example, "suddenly, everyone was anti-nuclear...Party conservatives and progressive members of the political opposition alike avowed their heartfelt opposition to the overwhelming nuclear threat in their area."[111] In campaigns for the local, city, and oblast soviets in January and February of 1990, almost every candidate in Khmelnitsky expressed opposition to the plant, and as soon as the new oblast soviet met there in April, deputies voted unanimously to halt construction on the Netishin reactors. The vote "set a precedent that was replicated across the republic," with local decision-makers demanding the right to determine whether nuclear power stations would be operated in their areas.[112]

As local projects foundered and details of Chernobyl's health impact continued to emerge, Soviet citizens grew bolder and more willing to question authorities' honesty and expertise -- all the way to the top. During one of his well-publicized walks among Soviet people, this time on the streets of Kiev in February, 1989, Mikhail Gorbachev was interrupted by an elderly woman who demanded to know what the Kremlin planned to do about two controversial nuclear reactors under construction in the Crimean peninsula. Gorbachev promised that if a group of American nuclear experts reviewing the plans concluded the location was unsafe, the project would be converted into a training facility.[113] Residents of the village of Stare Sharne in

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[111] Dawson, *Social Mobilization in Post-Leninist Societies: The Rise and Fall of the Anti-Nuclear Power Movement in the USSR* , 210.

[112] Ibid., 210-212.

[113] John F. Burns, "A Rude Dose of Reality for Gorbachev," *The New York Times* (Feb. 21, 1989) A3.

Narodychi, a farming district west of the 30-kilometer exclusion zone around Chernobyl, wrote an impassioned letter to *Literaturna Ukraina* stating that "During the three years that have passed since the Chernobyl catastrophe... residents have learned to distinguish truth from lies, and began to divide those concerned with the problems of the raion [district] into 'honest' and 'dishonest.'"[114] Anti-nuclear protest rallies grew larger and more vocal with each passing anniversary of the disaster. Twelve thousand people gathered in a Kiev soccer stadium to mark Chernobyl's third anniversary. They heard Ukrainian poet Dmytro Pavlychko declare that "All the lessons of Chernobyl [have] not yet been learned....Anyone being sent to work at Chernobyl should go there for one of two reasons: either to dismantle the station, or to assist in sanitizing the zone." Nuclear power operation, Pavlychko said, "must be guided by the wisdom of the people."[115]

Opposition to nuclear power quickly became the organizing principle for the Soviet Union's burgeoning environmental movement. Perhaps shortsightedly, Soviet authorities had for many years tolerated environmentalism as a harmless, non-subversive form of political protest. The protection of nature had thus become one of the few subjects upon which writers, intellectuals, and other thinkers could safely express dissident views. But the Chernobyl disaster energized scattered individuals and groups to combine forces in a more radical call for political change. In the spring of 1989, Zelenyi Svit chairman Shcherbak, an epidemiologist and novelist who had been moved by the events at Chernobyl to become an environmental activist, defeated six other candidates to win a seat in the new Congress of People's Deputies. While a member of the Congress, Shcherbak spoke against nuclear power, describing Chernobyl as part of a campaign of nuclear warfare waged by the Ministry of Nuclear Power against the people of the Soviet Union.[116] Observed Marples, "By its attacks on the bureaucracy and on the nature of industrial decision-making in Ukraine, and by its unceasing opposition to nuclear power plants" Shcherbak and Green World had "adopted a political stance that divorced [them] from contemporary Party ideology."[117]

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[114] *Literaturna Ukraina*, June 22, 1989; quoted in Marples, *Ukraine Under Perestroika*, 69-71.

[115] Ibid., 38. Translated by Marples.

As the Party's hold on power weakened, party ideology soon withered. In 1990 the balance of popular support in several Soviet republics shifted in favor of the environmental movement. Sixty thousand people attended a fourth-anniversary Chernobyl rally in Kiev. In a June survey of 96,000 Moscow residents, 54 percent expressed trust in the Green movement as against only 39 percent who said they trusted the Communist Party, and more than 70 percent said they were still concerned about radiation dangers from Chernobyl.[118] The Green movement had become popular "because the public could perceive, after Chernobyl, how their land was being systematically destroyed in the name of economic progress," Marples writes.[119]

In Ukraine, Green World members parlayed this support into the creation of a Green Party, whose platform castigated the Soviet nuclear establishment for its undemocratic, centralized command structure and for the danger its designs posed to health and the environment. The new party demanded nuclear energy's prohibition and offered legislation allotting two-thirds of state energy spending for the development of alternative and renewable sources.[120] As the number of plant cancellations and suspensions continued to mount, nuclear abolitionism gradually displaced the government's program of reform and expansion of the nuclear industry.[121] At its summer congress in 1990, the Communist Party of Ukraine itself announced a moratorium on nuclear plant construction.[122] In April 1994, more than three years after the Soviet Union's collapse, the government of independent Ukraine finally agreed to shut down the remaining undamaged reactors at Chernobyl, pending American help in finding alternative energy sources.[123]

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[116] Ibid., 155-156, 166.
[117] Ibid, 167-68.
[118] Reuters, "Chernobyl Rally Attended by Thousands," *The New York Times* (April 27, 1990) A6; Survey data reported in Feschbach and Friendly, 237.
[119] Marples, *Ukraine Under Perestroika*, 173.

After a period of inertia in 1986-1987, then, the Soviet people's reaction to Chernobyl closely mirrored the U.S. experience after Three Mile Island. In the five years following the disaster in Ukraine, no new reactors were commissioned, and work halted on 39.[124] Nuclear fission continued to provide a significant fraction of the USSR's total energy, but atomic power stations assumed a shadowy, menacing status emblematic of the Soviet Union's historical despoliation of the natural environment. Henceforth, any project that threatened human health or environmental quality would encounter significant public opposition. As Dawson concludes in her study of protest in the Khmelnitsky district, "mass participation in anti-nuclear rallies and petition drives (premised on genuine fears about the safety of neighboring nuclear power stations and the threat they posed to home and family) represented a major change in how the population viewed its relationship to the state."[125] Shcherbak confirms this observation in *Chernobyl: A Documentary Story*, an account of his three-month research journey through the Chernobyl region. 1986, Shcherbak writes, was the year when "we all suddenly matured, grew up by a whole epoch...We became harder and more exacting toward both ourselves and toward those who take responsible decisions, those in whose hands human existence and the fate of nature rest."[126]

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[120] Ibid., 171-72.

[121] William C. Potter, in "The effects of Chernobyl on Soviet decision-making for nuclear safety," *Impact of Science on Society* (no. 163) 257-67, provides an overview of this process.

[122] Marples, *Ukraine Under Perestroika*, 220.

[123] John H. Cushman, Jr., "Ukraine to Close Chernobyl Plant," *The New York Times* (April 10, 1994) 1, 12; Reuters News Service, "Ukraine Agrees to Seek Other Energy Source, Close Chernobyl," *The Boston Globe* (April 10, 1994) 21.

[124] Michael Dobbs, "Disaster, Nuclear and Bureaucratic," *The Washington Post National Weekly Edition* (May 6-12, 1991) 10-11.

The Fission of the Soviet State

While Chernobyl mobilized lay opponents of nuclear power to pursue and achieve changes in state technology policy that would have been unthinkable before the disaster, the broader political consequences of the catastrophe were even more momentous. The chain reaction leading to the Soviet breakup started with *glasnost* and was sustained by Chernobyl and by the fervor for political independence in the republics. When the Soviet Union finally disintegrated, it was in a burst of conflicting ideas about the responsibilities of the state, including its role in creating and managing hazardous technologies. Just as the radioactive fission products in a nuclear reactor's spent fuel rods can never be reassembled, nothing will restore the USSR's constituent states to their former unity -- a conclusion brought about by the gathering energy of popular outrage over Chernobyl and the other failures of Soviet Communism.

We have already traced Chernobyl's effects on the Soviet nuclear program up to the present day, but to understand the disaster's full political impact we must begin again in 1986. In the first days and months after the explosion, the only political question that occurred to Western political analysts was whether Gorbachev and his reform programs would survive the disaster. "The tragedy of Chernobyl has produced a season of internal crisis in Moscow," wrote Harrison Salisbury, a political correspondent specializing in Soviet affairs. The accident had struck, he observed, at a time when Gorbachev was gaining control over the party and state apparatus but was "not yet firmly in the saddle."[127] Like Krushchev after the U-2 incident in 1960, Gorbachev might have to abandon elements of his reforms in order to retain power. *Glasnost,* Salisbury predicted, would be the first to go. Cold Warriors in the West, as if they felt perversely vindicated by the new policies' looming extinction, warranted that only a fallback to their old, authoritarian ways would get the Soviets through the crisis. "The Soviet Union doesn't do stunning transformations," the editors of the *New York Times* smugly declared.[128]

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[125] Dawson, *Social Mobilization in Post-Leninist Societies: The Rise and Fall of the Anti-Nuclear Power Movement in the USSR* , 219.

[126] Yurii Shcherbak, *Chernobyl: A Documentary Story* (London: Macmillan, 1989) 2.

The early days of the disaster were indeed a time of official secrecy and reticence. It was only when radioactive particles from Chernobyl were discovered on the clothes of workers arriving at the Forsmark nuclear plant in southern Sweden that the West learned of the nuclear fire and its toxic cloud. The Soviets' official acknowledgement of the accident, when it came, was terse and cryptic; spokesmen seemed mainly concerned to reassure the world that life inside the Soviet Union was going on as usual. (And in fact, while the reactor smoldered 150 kilometers to the north, authorities in Kiev proceeded with a May Day parade and other outdoor celebrations). "When a crisis struck, the Kremlin reverted to its time-honored pattern of rationing information," wrote Serge Schmemann. "It was an approach rooted in a view that information is a tool of the state, and that domestic disasters must not be allowed to spread alarm or to raise questions about the wisdom or qualifications of the state. The greater the disaster, in this view, the greater the need to clamp down strict controls."[129]

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[127] Harrison Salisbury, "Gorbachev's Dilemma," *The New York Times Magazine* (July 27, 1986) 18, 30.

[128] "From Russia: Faces," *The New York Times* (Sep. 2, 1986) A18. As the editors of *The New Yorker* later observed, "When Gorbachev went on television sixteen days later to acknowledge the extent of the disaster, he was still viewed with deep suspicion by many in the West. It would take the collapse of the Berlin Wall and the Warsaw Pact, and revolutions in Eastern Europe and the Soviet republics, to show that his policy of *glasnost* was both genuine and irreversible." "Notes and Comment," *The New Yorker* (May 6, 1991) 31-32.

Within days after the disaster, however, the controls had unexpectedly begun to loosen. On May 6, *Pravda* published a detailed account of conditions at Chernobyl, and Boris Shcherbina, head of the government commission to which Legasov had been assigned, admitted in a Moscow news conference that authorities had at first "underestimated the scope" of the disaster.[130] More details followed. *Izvestia* remarked on May 9 that "there is no point in denying" that evacuation efforts in Pripyat and the surrounding area had been both tardy and inadequate.[131] As even Western experts agreed, Legasov's report to the International Atomic Energy Agency three months later was candid and exhaustive, at least in its technical details.[132] Though the disaster had occurred "at the worst possible time and in the worst possible region," and though full disclosure held out potentially grave consequences for the nuclear industry and for Gorbachev's economic plans, the new Party leadership foresaw that attempting to deny the truth would lead to even worse results.[133] "This was the first of many occasions when Gorbachev would be faced with an unexpected event that challenged his plans," one Party official later said. "His reaction was -- it turned out-- characteristic. He took the Chernobyl disaster as a prod to move farther and faster."[134]

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[129] Serge Schmemann, "The Russia Syndrome: A Reticent Response to a Nuclear Calamity," *The New York Times* (May 4, 1986) IV:4.

[130] David Marples, *Chernobyl and Nuclear Power in the USSR*, 12-15.

[131] Ibid., 25. On May 13, *Pravda* observed that the disaster had "highlighted bottlenecks" in emergency response plans and that local party leaders had been "psychologically unprepared" for accident conditions. Marples, 31.

[132] Alexander Sich, for example, writes that "the Soviets are to be commended for displaying a great deal of candor at the Vienna meeting in August 1986." He adds that the data in the report must be treated with caution since much of it was in summary form. It is now known as well that several pages of the report detailing radioactive fallout in Belarus and Russia were removed before the Vienna meeting. "I did not lie at Vienna, but I did not tell the whole truth," Legasov told the Soviet Academy of Sciences two months after the conference. See

Information, formerly considered "too precious to be recklessly handed about as if it were free," was now considered too volatile to be contained.[135] While politicians inside and outside the Soviet Union feared that knowledge of the disaster's severity would undermine the sense of renewed confidence and energy surrounding Gorbachev's reform agenda, Gorbachev himself may have seen that the disaster's lessons, once acknowledged, could be put to constructive ends. "The handling of the disaster underscored a Gorbachev refrain: that the Soviet bureaucracy is unwieldy and fragmented and discourages crisp decision-making," observed one political reporter.[136] If economic revival depended on the streamlining of government, then public displeasure over Chernobyl might be exploited as a purifying agent. "You keep up the pressure," Gorbachev told a Moscow crowd. "We'll press from the top, and you keep pressing from the bottom. Only in this way can

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Sich, *The Chornobyl Accident Revisited*, 70-71.

[133] Marples, *Chernobyl and Nuclear Power in the USSR*, 35.

[134] Quoted in Feschbach and Friendly, 14.

[135] Nicholas A. Ulanov, "Soviet Fear of the Knowledge Revolution," *The Wall Street Journal* (May 13, 1986) 30.

[136] Philip Taubman, "A Worst Case Scenario That Isn't a Scenario," *The New York Times* (May 11, 1986) E1.

perestroika succeed."[137]

Perestroika promised to help change the way nuclear energy was managed in the Soviet Union, for as Grigori Medvedev noted, "Chernobyl demonstrated the insanity of the command-administrative system."[138] In a speech to party officials at Chernobyl, Gorbachev promised that the republics would be given more autonomy to devise their own plans for energy and economic growth. New nuclear projects, Gorbachev said, "ought to undergo strict scientific examination for possible harm to the environment, and in disputed cases should be subject to a referendum."[139] The need for international assistance in the areas of plant safety, radiation monitoring, and health care after Chernobyl would also open Soviet society to a wealth of outside perspectives and information -- an especially important development for fledgling environmental groups like Zelenyi Svit. After the disaster, as William C. Potter, an analyst of Soviet nuclear energy, observed, "Most facets of the nuclear industry (outside the military sector) became a legitimate subject for scrutiny...Although the political leadership was not prepared to abandon its long-standing enthusiasm for and commitment to nuclear power, it was no longer able to suppress expert and public criticism of the nuclear power program or to conceal the inadequacies of the Soviet approach to nuclear safety."[140]

Nor was the leadership able to contain rising nationalist sentiment in the republics. In January, 1988, an unusual letter appeared in *Literaturna*

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[137] Burns, "A Rude Dose of Reality for Gorbachev," A3.

[138] Dobbs, "Disaster, Nuclear and Bureaucratic," 10.

[139] Bill Keller, "Gorbachev, at Chernobyl, Urges Environmental Plan," *The New York Times* (Feb. 24, 1989) A5.

[140] Potter is a professor of international policy studies at the Monterey Institute of International Studies. "The effects of Chernobyl on Soviet decision-making for nuclear safety," 258.

Ukraina indicting the USSR's 18-month-old Ministry of Atomic Power Engineering for its ill-conceived plans to construct 6,000 megawatts of new nuclear generating capacity in Ukraine. The thirteen Ukrainian scientists who signed the letter asserted that the new plants were unnecessary and would hurt farm production and the supply of fresh water. The Atomic Ministry was ignoring these obvious problems, the writers charged, because it wanted to preserve its "privileged, irrefutable authority" over Ukrainian nuclear development. Chernobyl had undone the myth that nuclear power plants are perfectly harmless, the letter stated, and one of the "moral-economic consequences" of the accident was that "the entire complex of problems involved in the development of nuclear energy in the Ukrainian SSR" must be re-examined, with Ukrainians themselves deciding whether and where to build new nuclear plants.[141]

The letter's plainly anti-Soviet tone epitomized Ukrainians' growing mistrust of the central government. Decades of quasi-colonial domination or "russification" had fostered a bitter discontent among the republic's population. Ruthless exploitation of Ukraine's nonrenewable resources, especially coal and iron ore, had left the republic's mines gutted, its workers poor and unhealthy, its cities polluted. Falling industrial output, quickening inflation, and ongoing shortages of food, housing, and consumer goods testified to the failure of economic restructuring. On top of all this came Chernobyl's radioactive fallout, which necessitated the decontamination of two million hectares of agricultural land (an area the size of Massachusetts) and the permanent abandonment of 150,000 once-fertile hectares.[142]

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[141] *Literaturna Ukraina*, January 21, 1988; quoted in Marples, *The Social Impact of the Chernobyl Disaster*, 271-74.

[142] Z. Medvedev, The Legacy of Chernobyl, 106.

For millions of Ukrainians, economic and political independence from Russia seemed the only escape from further abuses. Journalist David Remnick, in his Pulitzer Prize-winning 1993 volume *Lenin's Tomb: The Last Days of the Soviet Empire,* writes:

> As I traveled around the Union, opinions varied on when and where the old regime died...But it was in Ukraine that I found the most unifying event, the absolute metaphor for the explosion of the last empire on earth. On a trip to the western Ukrainian city of Lvov in 1989, I met with small groups of nationalists who promised that 'one day' their republic of over fifty million people, the biggest after Russia, would strike out for independence and do far more damage to the union than the tiny Baltic states ever could...Bogdan and Mikhail Horyn, brothers who had spent long terms in jail for their pro-independence activities before Gorbachev took power, said that while an independent, post-Soviet Ukraine may be years off, the old regime collapsed, practically and metaphorically, at 1:23 a.m., April 26, 1986, the moment of the nuclear accident at Chernobyl. That devastating instant had from the start been wrapped in a mystical aura. Within weeks of the accident, people realized that 'Chernobyl' meant 'Wormwood' and then pointed to Revelations 8:10-11; 'A great start shot from the sky, flaming like a torch; and it fell on a third of the rivers and springs. The name of the star was Wormwood; and a third of the water turned to wormwood, and men in great numbers died of the waters because it was poisoned.' The accident at Chernobyl embodied every curse of the Soviet system, the decay and arrogance, the willful ignorance and self-deception.[143]

Indignation over Chernobyl and all it represented became a constant undertone in the clamor for Ukrainian self-rule. After the disaster, "Ecological consciousness became a part of our national consciousness," said a leader of *Rukh,* the republic-wide reform movement of which Green World was one part. Protests against nuclear power, the leader said, "were part of the larger protest against the empire itself."[144]

Disagreement over the management of the Chernobyl cleanup was a major ingredient in deteriorating relations between Moscow and the republics. Regional Party officials, whose power and prerogatives were already threatened by Gorbachev's reform programs and who therefore had little to lose, added their voices to those of environmental groups criticizing the central government's handling of the cleanup. Grigory Revenko, first Party secretary of the Kiev region, complained to *Pravda* in April 1989 that safety standards were slipping at the three reactors still operating at Chernobyl.[145] In July, Byelorussian officials released radiation measurements proving that the central government should have evacuated an additional 100,000 people from areas contaminated by the explosion.[146] Scientists from the Ukrainian Academy of Sciences contended that soil contamination levels and individual radiation doses rated as "safe" by the central government's scientists were far too high. Moreover, the scientists believed that the "sarcophagus" hurriedly built to contain the ruined reactor was leaking too much radiation into the environment and that an entirely new structure was required. "The possibility of further failure grows with time, and if the republic does not exert local influence, the job will not be done right," asserted Ukrainian biologist Dmitri Grodzinsky.[147]

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[143] Remnick, *Lenin's Tomb,* 243.
[144] Feschbach and Friendly, 232-33.

Even in Byelorussia, a docile region long lacking a sense of national identity separate from Russia, Chernobyl stirred embers of resentment toward Moscow. Fallout had idled five percent of the farmland in the southern Gomel district, just across the Ukrainian border from the plant, and uprooted hundreds of thousands of residents from 170 villages. "There's still something bad, something poisonous out there," said one grandmother three years after the evacuation. "The authorities have the best intentions, but they better invent something else to replace atomic power."[148] Fifteen thousand protestors carried the banned Byelorussian national flag through the capital city of Minsk in September, 1989, demanding further evacuations from contaminated areas and the resignation of the republic's Party chief.[149] A correspondent traveling through condemned villages in the republic observed that Chernobyl had become "a special Byelorussian cry for identity, a cause for vying with the central Government, viewed so long with fear and suspicion."[150]

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[145] Associated Press, "Chernobyl's Safety Questioned," *The New York Times* (May 1, 1989) A7.

[146] Francis X. Clines, "Soviet Villages Voice Fears on Chernobyl," *The New York Times* (July 31, 1989) A3.

[147] Francis X. Clines, "A New Arena for Soviet Nationalism: Chernobyl," *The New York Times* (December 30, 1990) A1, A8.

[148] Francis X. Clines, "Once Again, Chernobyl Takes a Toll," *The New York Times* (Sep. 30, 1989) A4.

By 1991, then, politics in the sovereignty-minded republics had undergone a remarkable transformation. Chernobyl and the faltering economy had largely discredited the Communist Party. The accident, according to Yurii Shcherbak, had exposed "all the secrecy, the callousness, the self-interest. On May Day [the Party] ordered children into the streets. People don't forgive when it affects their children. They never forgave. They began to curse the Party."[151] In Ukraine, officials instituted a new national currency to supplant the ruble, and free elections brought to power a fractious yet reform-oriented parliament that included several members of the Green Party. To win election, one Chernobyl official reported ruefully, "a candidate needed only two issues: throw out Article Six," which guaranteed the Party's leading political role, "and close Chernobyl."[152] Far from remaining under Russia's thumb, Ukrainians now pondered only whether -- and for how long -- Moscow should retain any influence at all. As David Marples wrote, "From total disillusionment at the ability of the popular will to bring about any change in economic planning, we now have a situation in which one cannot build a factory without republican approval, and one cannot acquire such approval without first asking the public for its support...Events such as Chernobyl -- paradoxically -- have been instrumental in uniting Ukrainians, in forcing them to recognize that it is their fate and that of their country that is being threatened."[153]

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[149] Reuters, "Marchers in Minsk Demand Further Chernobyl Cleanup," *The New York Times* (Oct. 1, 1989) A9.

[150] Clines, "Once Again, Chernobyl Takes a Toll," A4.

[151] Serge Schmemann, "Chernobyl Within the Barbed Wire: Monument to Innocence and Anguish," *The New York Times* (April 23, 1991) A6.

[152] Aleksandr Zenyuk, head of the department of foreign relations at the Chernobyl atomic station. Quoted in Schmemann, ibid.

As 1991 ended, the storm of change initiated by Chernobyl spun to its most furious pace yet. In October an explosion outside one of the three remaining reactors at Chernobyl ripped a 2,500-square-meter hole in the roof of a generator building, and the next month the Ukrainian parliament voted to close the newly damaged unit, overriding the Soviet Atomic Ministry's assessment of the accident as minor. The two reactors still in operation at the Chernobyl site, the parliament decreed, should also be shut down "in the shortest possible time and not later than 1993."[154] On December 1, meanwhile, the parliament proclaimed Ukraine's sovereignty from the Soviet Union. The new nation joined the Commonwealth of Independent States, which explicitly rejected the Soviet Union's claim to nationhood. On December 11 a parliamentary commission demanded that 18 Ukrainian and Soviet Party officials, including Mikhail Gorbachev, be prosecuted for conspiring to conceal the true extent of the Chernobyl fallout.[155] But the question of the Soviet leader's responsibility for the disaster would soon become academic. The chaos in Moscow touched off by August's failed Kremlin putsch rapidly culminated in the suspension of the Communist

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[153] Marples, *Ukraine Under Perestroika*, 223.

[154] Yuri Kanin, "Ukraine will close reactors," *Nature* (Nov. 17, 1991) 8. A lack of electricity from other sources would eventually undo this decision.

[155] Associated Press, "Ukrainians Demanding Trial for Gorbachev on Chernobyl," *The New York Times* (December 12, 1991) A12.

Party, Russian President Boris Yeltsin's ascent to power, Gorbachev's resignation, and the abolition of the Soviet Union itself.

The citizen campaign against Soviet nuclear technology had not begun as a movement with radical political objectives; even Yurii Shcherbak, for several years after the disaster, had continued to believe in "the future of the Soviet system under Gorbachev."[156] But in a post-Chernobyl world, technology and politics had become inseparable. The disaster came to symbolize not just government incompetence and environmental mismanagement, but also Moscow's imperialistic influence over people's lives and livelihoods in the republics. Alexander Sich (who is of Ukrainian descent and uses the Ukrainian "Chornobyl" as opposed to the Russian "Chernobyl") writes of his time at the plant site from 1991 to 1993 that "as far as Ukrainians were concerned, the Chornobyl accident...forced the whole issue of external control of the republic's resources into the public arena Chornobyl brought to light many of the injustices and inefficiences of the Russian-controlled Soviet system; and because of this it has been credibly argued that as a watershed that forced then General Secretary Gorbachev to accelerate and more fully implement his policy of glasnost, Chornobyl was a major factor that led to the demise of the system and of the Soviet Union."[157]

Aleksandr Yakovlev, Gorbachev's right-hand man, looked back on the tumultuous years 1985-1991 in an interview with David Remnick. Once *glasnost* and *perestroika* had been given their initial momentum, Yakovlev said, they acquired their own inexorable "logic of development":

> Our baseline principle was that some things could be improved: more democracy, elections, more in the newspapers -- limited, but slightly more open -- the management should be improved, centralization should be less strict, power should

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[156] Marples, *Ukraine Under Perestroika*, 157.
[157] Sich, *The Chornobyl Accident Revisited*, 88.

> be redistributed somewhat, maybe the functions of the Party and the government should be divided...In 1985 we started implementing things for the first time so that our words were matched by deeds. But as soon as these words became reality, a logic of development began to develop, and that dictated the next steps...This logic of development led us to the 'conclusion' that the concept of improvement will not do us any good. One can fix up a car, add some oil, tighten some bolts, and you can drive on. But with a social organism you cannot always do this. It is not always enough. It turned out that everything had to be made over.[158]

Chernobyl occurred just as the reformers' words were becoming reality, imparting to the "logic of development" a momentum which the reformers themselves found they could not restrain. Gorbachev, Yakovlev, and their circle were thus swept up in their own revolution, the pace of which the nuclear disaster had speeded substantially. Natalya Ivanova, a Moscow literary critic, described the swiftness of the final disintegration with an apt simile. Gorbachev, she said, was like "the man who gave the orders to begin the fateful experiment at Chernobyl. He wanted to refine the machine, but the machine went out of control and exploded."[159]

"The Beginning of Wisdom"

Little has occurred since the sudden liberation of the post-Soviet nations to calm the nerves of a watchful world. Instituting democratic government and market economies among populations still ambivalent about both, while at the same time combatting ethnic divisions, rampant nationalism, and lurking authoritarianism, has proved more challenging than any of the new nations' leaders predicted before the breakup. Scarcity, hyperinflation, crime, and the greed of a powerful "bandit bureaucracy" made up in good part of former Communists have left many citizens disgruntled over the style and pace of free-market reforms, and rightist demagogues stand ready to exploit this discontent. Pessimists might aver that whereas the old Soviet Union was a collection of leaky life-rafts roped together by the Communist order, each of the sovereign republics is now free to sink on its own.

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[158] Remnick, *Lenin's Tomb*, 297.
[159] Ibid., 502.

The future of nuclear technology in the former Soviet Union seems no less worrisome. In 1992 Yeltsin transferred the property of the Soviet Ministry of Atomic Power Engineering to a new Russian ministry, "effectively prolong[ing] the life of...the nuclear 'monster' of the former regime, with its huge network of secret towns, plants, and waste dumps."[160] Over the objections of Yeltsin's environmental advisors, the new ministry soon announced that Russia would finish 30 more nuclear power plants, including one mothballed RBMK, by the year 2010. "The nuclear industry is protecting its own," says Lydia Popova, director of energy programs at Moscow's Socio-Ecological Union, an umbrella organization for 150 environmentalist groups. "By blindly supporting the expansion of publicly unpopular and unaccountable nuclear programs, the government will slow the democratization of Russia and the development of a civil society with civil law."[161]

Despite the ongoing civil and technological turmoil in the former Soviet Union, however, it would be foolish to wish for a return to the comforting certainties of the Cold War era. Most of the economic, political and environmental crises proliferating across Russia and the former republics are not new but are the legacies of the USSR's misguided experiment with centralized socialism. It is unlikely that the pre-Chernobyl order, had it continued to exist, would have faced these problems openly or effectively. Though the old Communist bureaucracy was in charge of everything, it took responsibility for nothing. The citizens of the former Soviet Union -- rid of the need to fear heterodoxy, able to form diverse political movements, and presented with meaningful choices at the ballot box -- are, if nothing else, finally free to confront the reality of their predicament. "If there is any bright spot in this sketch of a nation on the edge of ecological and human disaster," Feshbach and Friendly wrote just before the breakup, "it is in the awareness that Soviet citizens and leaders...show of the gravity of their crisis. That consciousness can lead to change; it is at least the beginning of wisdom."[162]

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[160] Vera Rich, "Russia breathes life into 'nuclear' monster," *New Scientist* (Feb. 29, 1992) 13.

[161] Lydia Popova, "Russia's nuclear elite on rampage," *The Bulletin of the Atomic Scientists* (April, 1993) 14-15, 47. The persistence of the nuclear option in Russia can also be attributed to severe power shortages; as Marples has pointed out, "The collapse of the Soviet Union created a paradox. It slowed progress in dealing with the effects of Chernobyl and created energy shortages that have strengthened the nuclear power lobby today." David Marples, "Chernobyl's Lengthening Shadow," *The Bulletin of the Atomic Scientists* (Sep. ,1993) 41.

Industrial technology, with its unseverable links to health, safety, prosperity, and environmental quality, will continue to be one of the most important arenas for democratization. The social consequences of the Soviet government's industrial and military policies are coming to light after decades of secrecy and denial, and environmentalists now recognize that nuclear energy -- so important as an early focus for activism -- is only one of myriad enterprises in need of reform. The new republics' environmental problems are similar in nature to those in the United States, but vastly greater in scale. The costs of remediating toxic and radioactive contamination, curbing air and water pollution, and instituting sustainable agricultural practices in Russia will exceed available resources for decades to come. Fortunately, the breakdown of centralized industrial planning and management has elevated many environmentalists to positions of power, and public-interest groups like Socio-Ecological Union now fulfill the critical need for outside monitoring of government activities. Change will also be reinforced by economic reality: no one can afford another Chernobyl.

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[162] Feschbach and Friendly, 11-12.

It would be inaccurate, furthermore, to portray the threatened resurgence of nuclear energy production in Russia as a repudiation of Chernobyl's lessons. The majority of the nuclear construction projects shelved after Chernobyl will never be resumed. Even the Russian nuclear ministry's most ambitious expansion plans, should they get past the new web of environmental controls, would leave the country far behind the production goals set by the Soviet Union in 1986. And while fifteen RBMKs are still operating today and a sixteenth is scheduled to be put into operation this year, a new openness to inspections by the International Atomic Energy Agency and technical assistance from Britain, Canada, France, Germany, Japan, Sweden, and the United States has reduced the risk of future disaster. Continuing concern over the RBMK's fundamental design flaws may eventually generate enough international financial assistance to allow their abandonment.[163]

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[163] Seth Shulman, "Risky Reactors," *Technology Review* (Aug./Sep., 1993) 18-19. Though secondary to the disaster's effects in the former Soviet Union, the importance of Chernobyl for Western technological politics should not be overlooked. It is simple enough to ascribe the disaster, as I have done, to flaws in the Soviet Union's industrial philosophy. "This position has the double virtue not only of being accurate in many respects -- the reflexive secrecy and pervasive incompetence within the Soviet nuclear enterprise made a major accident all but inevitable -- but also of implying that such a thing could never happen elsewhere," the editors of the *New Yorker* wrote in 1991. They added, however, that "The historical record...suggests that the Soviet and the American experiences in attempting to master atomic energy over the past forty years have been far more alike than not." ("Notes and Comment," *The New Yorker* , May 6, 1991, 31-32.) The protestations of nuclear power's proponents that "Chernobyl can't happen here," though correct in a narrowly technical sense, missed the real point. (See, for example, Hans Bethe, "Chernobyl: It Can't Happen Here," *The New York Times* , May 2, 1992, A25; U.S. Committee for Energy Awareness, "Energy Update: Why what happened at Chernobyl didn't happen at Three Mile Island," advertisement, *The Wall Street Journal* , May 12, 1986, 7.) American nuclear plants feature their own set of design flaws, and as we learned in Chapter 3, the origins of these flaws stretch as far back into the political history of the United States as the RBMK program does into the Soviet Union's. As Kennedy P. Maize, senior energy analyst for the Union of Concerned Scientists, wrote in 1986, "The Soviet nuclear plants are inherently dangerous. Unfortunately, so are ours. Our plants also make too many demands on operators, requiring them to make literally life-and-death decisions in a matter of seconds. Russia-bashing won't

Disaster has united the people of Russia, Ukraine, and the other former Soviet republics many times. Indeed, the history of these nations can be viewed as a series of devastating catastrophes interrupted by periods of equally impressive cultural and economic rebound. But the region's disasters, usually in the form of armed invasions, have almost always struck from the outside. The Chernobyl explosion, by contrast, helped force the Soviet people to confront the enemy within: the reality that the corrupt Communist order had plundered the USSR's resources, repressed and sickened its people, and despoiled the natural environment in the name of state power and a flawed socialist ideology. Acknowledging this truth and their own silent complicity in it required an act of immense political bravery on the part of Soviet citizens, for in discarding the Communist system and becoming participants in their own futures they have thrust themselves into a difficult and dangerous new world: the world of democracy. If this political experiment outlasts the disaster's radioactive legacy, then Valerii Legasov and the legions of other Chernobyl victims will not have given their lives in vain.

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cure that situation." ("Technological Hubris," *The Wall Street Journal*, Sep. 9, 1986, 29.)

Chapter 6

TECHNOLOGICAL CITIZENSHIP

Ring the bells that still can ring.
Forget your perfect offering.
There is a crack in everything.
That's how the light gets in.

— Leonard Cohen,
"Anthem" (1992)

After journeying through accounts of two blackouts, a chemical leak, and two meltdowns, the reader is entitled to ask whether these stories have anything new to teach us today, years after the disasters themselves have ended. The direct *medical* and *social* consequences of these catastrophes, of course, will continue to be felt for decades, especially in India and the former Soviet republics. Each failure has also led to *technological* changes that have made the systems in question nominally safer. But the main reason for examining these well-known events anew has been to explore the proposition that the major technological disasters of recent years add up to something more than a collection of regrettably "normal" accidents: that they are, in fact, helping to redefine the meaning of democratic participation in modern societies.

Rapid technological change in the twentieth century -- in particular, the spread of large, complex technological systems -- has placed the terms "citizenship" and "democracy" under stress. The technologies that provide us with cheap energy and abundant food, that let us communicate with one another instantaneously across great distances, that carry us around the globe at great speed -- that have, in other words, allowed us to transcend many of the limitations of our immediate environments -- have all been purchased in the currency of local control. Large technological systems, to use Anthony

Giddens' terminology, are "disembedding mechanisms" that "remove social relations from the immediacies of context."[1] They force people to place their welfare in the hands of far-away experts whom they have never met and whose expertise must remain an article of faith. For ordinary individuals, "participation" in these systems is often limited to the level of consumerism: decisions about whether to use or not to use, to buy or not to buy. In theory, existing forms of representative government provide the formal means of "changing the rules" under which these systems operate, should this become necessary to maintain safety or efficiency. In practice, the political power held by large technological organizations often blocks citizens' access to the governing process.

In this final chapter, I argue for an understanding of large-system failures that focuses on their serendipitous power to prompt people to reclaim active roles as citizens. Throughout this study, I have attempted to demonstrate the truth of the widening perception that growing size and complexity add to the instability of large technological systems. Through the enormous media attention they generate, technological catastrophes disclose to a wide audience a startling possibility: no one is truly "in control" of these technologies. Despite all attempts to centralize and automate control, the seeds of catastrophic failure lay dormant within thousands of components scattered throughout the systems. Once underway, moreover, breakdowns often propagate faster than any human being can counteract them. The "spectacle of suddenly vanishing competence" that the public sees under such conditions reveals that the claim of total competence was a pretense from the start. *If complex, tightly coupled systems are inherently unstable -- defying*

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[1] Anthony Giddens, *The Consequences of Modernity* (Cambridge, U.K.: Polity Press, 1990) 27-29.

absolute technical control -- then the only real "control" people have over them is political, residing in decisions about whether to build these systems in the first place, for whom, and in the service of what social needs, and, once the systems are built, how best to guard against the inevitable breakdowns.

Operating large systems on a day-to-day basis is both a technical and a political process, involving wide-ranging choices about the social and technological arrangements within which people must structure their lives and about the hazards to which they will be subjected. System failures thus create the potential for the reorganization of control. After most of the disasters I have described, the collapse of *technological* control activated grassroots challenges to established patterns of *political* control. In order to mount these challenges, people had to reassert their functions as citizens, functions that had grown unfamiliar through disuse. They had to build their own understandings of the workings of complex technologies, and then apply this knowledge in organized movements for change. The cases provided here demonstrate that the civic transformations accompanying large-system failures are at the very center of the cultural meaning of technological disasters.

Ulrich Beck, the German sociologist, is one of the few analysts who have recognized these developments. In Beck's view, modern nations have evolved into "risk societies" in which everyone, rich and poor alike, is equally threatened by reactor accidents, chemical catastrophes, toxic wastes, and other unwanted side-effects of industrialization. Basic social conflicts therefore no longer revolve around property, profit, or the relative deprivation of the middle and lower classes, but around the "systemic causes" of industrial hazards and how they should be combatted.[2] Beck writes:

> Socially recognized risks...contain a peculiar political explosive: what was until now considered unpolitical becomes political -- the elimination of the causes [of risk] in the industrialization process itself. Suddenly the public and politics extend their rule into the private sphere of plant management -- into product planning and technical equipment...In smaller or larger increments -- a smog alarm, a toxic spill, etc. -- what thus emerges in risk society is the *political potential of catastrophes.* Averting and managing these can include a *reorganization of power and authority.* Risk society is a *catastrophic* society. In it the exceptional condition threatens to become the norm.[3]

Beck's characterization of the "risk society" is marred by his neglect of the fact that the social distribution of technological hazards is highly *unequal,* as the poverty surrounding most industrial districts and recent studies of "environmental racism" make clear.[4] These inequities are precisely the issue in many local disputes over the placement of hazardous waste incinerators, repositories for radioactive wastes, and other less-than-desirable facilities.

But Beck is nonetheless correct that catastrophes show the formerly "unpolitical" -- the design histories of nuclear plants, operating practices at chemical factories, the computerization of cybernetic control systems, and so forth -- to be, in fact, deeply political. And since all political issues are, in theory, decidable through democratic means, disasters eliminate technical expertise as a prerequisite for involvement in the management of technological systems. Disasters are therefore opportunities for the exercise of citizenship in realms where it previously had little meaning. As large technological systems grow larger, more interconnected, and more vulnerable to breakdown, these opportunities become more frequent: "the exceptional condition threatens to become the norm."

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[2] Ulrich Beck, *The Risk Society: Towards a New Modernity* (London: Sage Publications, 1986) 39-40.

[3] Ibid., 24. Emphasis in original.

[4] See, for example, Eric Chivian, et al., eds., *Critical Condition: Human Health and the Environment* (Cambridge, Mass.: MIT Press, 1993).

One thing attention to technological disasters has *not* done, however, is turn the public against scientific and technological innovation, as some experts feared might happen. After an embarrassing and well-publicized series of technological failures in the spring of 1979 -- Three Mile Island, the Skylab satellite's premature reentry into the atmosphere, and the deaths of 275 people in a DC-10 crash in Chicago[5] -- a group of scientists met at Harvard's Kennedy School of Government to discuss their responsibility to communicate with the public after such disasters. At the meeting Alan McGowan, president of the Scientists' Institute for Public Information, accused the *New York Times*, the *Washington Post*, and other media outlets of "attempting to discredit, or saying everybody else was trying to discredit, the scientific community." The public shared a basic faith in science and technology, but they might lose that faith if journalists told them often enough that they had, McGowan worried.[6]

Though aggressive media coverage of disasters continued, the feared public disenchantment with science and technology never materialized. Throughout the nineteen-eighties and into the nineties, the majority of Americans still believed that the benefits of scientific research and technological innovation outweighed the harms, opinion polls showed. Although a substantial number, 75 percent, said in a 1982 survey that science and technology "often get out of hand, threatening society instead of serving it," scientists and engineers remain among the best-regarded professional groups, and the American public continues to expect significant advances in science and technology in the future.[7] Moreover -- and this hardly needs saying -- technologies like the electrical grid, nuclear power plants, chemical factories, and the space shuttle *continue to operate* today, even after the spectacular failures of the last three decades. The demands for outright renunciation one might have expected from a public thoroughly outraged by these disasters have not been heard.

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[5] For an innovative treatment of the Chicago DC-10 crash of May 25, 1979, see John H. Fielder and Douglas Birsch, eds., *The DC-10 Case: A Study in Applied Ethics, Technology, and Society* (Albany: State University of New York Press, 1992) 8-9, 207-246.

[6] Eliot Marshal, "Public Attitudes to Technological Progress: Scientists Fear Engineering Accidents of 1979 May Turn Public Against Science," *Science* (July 20, 1979) 281-85.

But the civic aftershocks of large-system breakdowns may not be measurable by such crude standards. One lesson from the incidents we have reviewed is that citizen responses to disaster can take a number of outward forms, depending on political conditions in the society where the disaster occurs and on the resources and ambitions possessed by the citizens themselves. If the results fall short of outright renunciation, it is because this is rarely a recognized goal to begin with. What unites these movements, rather, is citizens' desire to seize some measure of decision-making power over dangerous and influential technological systems, so that the dangers might be reduced and so that the systems themselves might be made more responsive to local needs and concerns.

The evidence of the previous chapters has powerfully confirmed Charles Perrow's argument that given a certain level of complexity and tight coupling in a technological system, occasional catastrophic failures are inevitable. But neither Perrow nor other analysts have fully explored the cultural meaning of this observation and its impact on democratic politics. Throughout, my claim has been that the most famous technological disasters of the recent past have shared more than just common technical and organizational origins:

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[7] Northern Illinois University Public Opinion Laboratory, "Public Attitudes Toward Science and Technology," a recurring chapter in National Science Board, *Science & Engineering Indicators* (Washington, D.C.: Government Printing Office, 1980, 1982, 1987, 1989, 1990 -).

they have also struck common political chords among the public. Geography has brought out different tones in different places, but the key, *democratization*, has remained constant. Drawn together, the case studies furnish proof that disasters have helped members of technological societies improve their ability to govern themselves through at least three basic mechanisms, which I will detail below: challenges to technological design; challenges to technical authority; and expanding definitions of citizenship. Each, in its own way, has helped to make large technological systems more democratic.

Before I continue, however, the sense in which I have been using the word "democratic" needs more clarification. Political theorists have fought long and hard over the meanings of words like "democracy." I agree with Richard Sclove, who wrote in a 1987 study entitled "The Nuts and Bolts of Democracy: Democratic Theory and Technological Design" that democracy is "a necessary background condition for enabling people to develop individual autonomy, and to debate and decide together whatever else, aside from democracy, should matter to them." At the core of any democratic social order should be institutions that "provide members with equal and extensive opportunities...to participate in determining the collective conditions of their existence."[8] Plainly, of all the means by which modern societies structure the "collective conditions of existence," large technological systems are among the most significant. Just as plainly, few of these systems incorporate ways for ordinary people to participate in their operation -- nor could they continue to function if they did so, since operating these systems requires specialized knowledge and experience. Deciding whether these systems are "democratic," therefore, requires that we first distinguish between *who operates them* on the one hand and *who decides they should be operated, and at what social cost*. on the other.

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[8] Richard Sclove, "The Nuts and Bolts of Democracy: Democratic Theory and Technological Design," delivered at the 1987 Annual Meeting of the American Political Science Association, 4. See also Richard Sclove, *Technology and Freedom: A Prescriptive Theory of Technological Design and Practice in Democratic Societies,* Ph.D. Dissertation, Dept. of Political Science, Massachusetts Institute of Technology, June, 1986, chapter 2; forthcoming from Guilford Press.

Large technological systems are a class of what Giddens has called "expert systems," by which he means medical care, traffic planning, architecture, and similar examples of the "systems of technical accomplishment or professional expertise that organize large areas of the material and social environments in which we live today."[9] Our own knowledge of these systems is usually minimal, yet we continuously place enormous confidence and trust in them. In return, we gain varieties of autonomy unavailable to most pre-modern peoples: freedom from darkness, cold, hunger, and an early death; freedom to acquire information about people and events far away; freedom from being bound all our lives to a particular geographical location. In one sense, then, the question of democracy is unrelated to the question of trust in expert systems. We allocate trust (and money) to these systems because we desire the benefits they provide. If we come to believe that the costs outweigh the benefits, or that the experts in charge are not worthy of our trust, we withdraw that trust. It is not correct simply to call this withdrawal "democratic," any more than it is correct to say that our trust in airplanes, pilots, and the systems of air traffic control involved in transcontinental jet travel is "undemocratic."[10]

But there is a broader sense, I believe, in which democracy and the allocation of trust are intimately related. According to Sclove's criteria, a society whose members were free to place their trust in existing systems or to withdraw that trust, but who were rarely given the opportunity to specify *what kinds of systems* they found intrinsically trustworthy or to work to bring existing systems into accordance with these ideals, would be highly undemocratic. Yet this is exactly the society in which we live. As Giddens writes, "The reliance placed by lay actors upon expert systems is not just a matter...of generating a sense of security about an independently given universe of events. It is a matter of the calculation of benefit and risk in circumstances where expert knowledge does not just provide that calculus but actually *creates* the universe of events."[11] Our freedom to choose which systems to trust and how far to trust them, in other words, is bounded by the systems themselves. This is what Ulrich Beck means by the "risk society": no one can be safe from the globalized hazards posed by modern technological systems, since no one can completely opt out of these systems. "Trust," Giddens concludes, "is much less of a 'leap to commitment' than a tacit acceptance of circumstances in which other alternatives are largely foreclosed."[12]

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[9] Giddens, *The Consequences of Modernity*, 27.

[10] I owe this formulation to Kenneth Keniston. (Personal communication, July 12, 1994.)

The term "democratization" may logically be applied, therefore, to any social or technological change such that *decisions about the kinds of risks and benefits created by the construction and operation of large technological systems are opened to broader, more direct public participation.* Citizen challenges to existing systems may begin with the withdrawal of public trust in professional expertise (technical authority) or in the machines that embody that expertise (technological design) or both. These withdrawals are only the first steps, however, toward a more democratic technological order. Equally important are efforts by ordinary people to remap the boundaries of citizenship in a technological age. People must "authorize themselves," in a sense, to contest and transcend institutionalized technological hazards.

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[11] Giddens, *The Consequences of Modernity*, 84. Emphasis in original.
[12] Ibid., 90.

Challenges to Technological Design

Most philosophers and essayists searching for ways to counteract modern technology's corrosive effects on citizenship surrender from the start all hope of modifying *existing* technologies to make them more compatible with democratic forms of living. They prefer instead to begin with a clean slate, banking on the success of movements for so-called "alternative" or "appropriate" technologies. In Langdon Winner's words, these movements "seek to devise technologies which offer genuine alternatives to the large-scale, complex, centralized, high-energy life forms which dominate the modern age."[13] Particularly heartening to alternative-technology advocates are experiments like the aptly-named UTOPIA project in Sweden, intended as an antidote to the "cybernation revolution." There, workers and managers in the newspaper industry collaborated with computer scientists to design a flexible, decentralized electronic page-production system that built upon workers' existing skills rather than outmoding them.[14]

Great effort and creativity have gone into such projects in both the developed and the developing worlds, but one basic fact will always stymie the alternative-technology movement: the slate is never clean. A democratization program that ignores this fact -- that accepts the current technological infrastructure as unalterable and merely aims to create shadow technologies which might in some ideal future gain ascendancy -- will achieve few visible changes in the near term.

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[13] Langdon Winner, "The Political Philosophy of Alternative Technology: Historical Roots and Present Prospects," *Technology in Society* (Vol. 1, 1979) 75-86.
[14] Langdon Winner, "Citizen Virtues in a Technological Order, " *Inquiry* (35) 356-57.

By paying greater attention to *existing* systems during and after technological disasters, meanwhile, many citizens have achieved a working understanding of the messy realities of technological power, one that promises to serve them better than any amount of faith in the future of alternative technologies. At the heart of this achievement is a process of *learning* and *experience*. Disasters uncork a flow of previously hard-to-come-by information about the ways technological systems come into being, how they are managed and regulated, the kinds and amounts of energy they employ and how this energy is controlled, and so forth. Through direct experience of technological breakdowns -- or, more often, through media reports -- people absorb this information and incorporate it into their previous (usually sketchy) understandings of technological systems. Since disasters are, by their very nature, alarming and undesirable events, the revised citizen understandings they foster can only be more cautious, skeptical, and critical than before.

This process was at work in each of the episodes we have examined. When the lights went off in New York City and the rest of the Northeast in November, 1965, people were moved to ponder the fallibility of the largest technological system of all: the electrical grid. Press coverage of the blackout emphasized the dauntingly complex geography of utility interconnections and the futile efforts of utility managers to stem the cascading power failure, leading customers of Consolidated Edison and other utilities to question whether such basic comforts as electricity could be taken for granted any longer. The 1977 New York City blackout renewed these worries and touched off a search for ways to make the nation's energy system more resilient and user-controllable. Three Mile Island, meanwhile, produced the revelation that mundane failures like a clogged air line, a stuck valve, a hidden light on a control panel, and operator misjudgments based on shaky instrument readings could combine to bring an American-style nuclear reactor to the verge of catastrophe. The accident prompted TMI's neighbors and millions of others to conclude that nuclear power is, as one woman commented, "a technology that's really gotten away from us."[15]

After the Bhopal tragedy and its sequel in West Virginia exposed slipshod operating practices and a shocking inattention to safety among Union Carbide managers, no one living downwind from a chemical plant could feel altogether safe from airborne toxic releases. And as *glasnost* took effect in the waning days of the Soviet Union, allowing average citizens to obtain accurate information about the causes of the Chernobyl explosion and about technical problems at other nuclear plants, people across Ukraine and other republics were sufficiently alarmed and emboldened to speak out against one of the Soviet Union's proudest technological accomplishments.

The point is that these disasters persuaded some people to stop seeing large, pervasive technological systems as impervious to outside influence. In each case, what was once solely the domain of technical experts -- details of design, operation, and management -- was opened to review and criticism from thousands. Though these were revolutions in thought and attitude more than action, they prepared the way for later, more substantive changes in the political and technological spheres. The changes began to bring to life the idealistic closing words of Mumford's *The Myth of the Machine*: "For those of us who have thrown off the myth of the machine, the next move is ours: for the gates of the technocratic prison will open automatically, despite their rusty ancient hinges, as soon as we choose to walk out."[16]

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[15] Quoted in the interview section of Raymond L. Goldsteen and John K. Schorr, *Demanding Democracy After Three Mile Island* (Gainesville: University of Florida Press, 1991) 51-111.

In all of this, the broadcast and print media played a crucial part. Most people, even if they live in the area of a disaster, look to television, radio, newspapers, and newsmagazines to explain the technical and political context of such events. How well journalists convey that context (or conversely, how many of them sink to the level of shrill sensationalism) can have a fundamental impact on the quality and agenda of public debate after a disaster. After a quarter of a million Pennsylvanians fearing radiation from Three Mile Island fled their homes in March, 1979, many critics in government and industry charged that the press had botched the story, presenting an inaccurate and overly alarming picture of the actual events inside the Unit 2 reactor. Media analysts, however, produced convincing evidence to the contrary. Despite the seriousness of the accident, only one-quarter to one-third of the statements made by the media during the first week after the meltdown were alarming or negative, one study found, and the alarming statements that were used echoed information provided by officials.[17]

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[16] Lewis Mumford, *The Myth of the Machine: The Pentagon of Power* (New York: Harcourt, Brace, Jovanovich, 1964, 1970) 435.

[17] Mitchell Stephens and Nadyne Edison, "News Media Coverage of Issues During the Accident at Three Mile Island," *Journalism Quarterly* 59 (Summer, 1982) 199-204, 259. The media's coverage of Three Mile Island has been analyzed perhaps more exhaustively than that of any other technological disaster. See also Peter M. Sandman and Mary Paden, "At Three Mile Island," *Columbia Journalism Review* 18 (July/Aug. 1979) 43-58; Public's Right to Know Task Force, *Staff Report to the President's Commission on the Accident at Three Mile Island.* (Washington, D.C.: Government Printing Office, 1980); Michael Fenichel and Peter Dan, "Headlines from Post and Times on Three Mile Island," *Journalism Quarterly* 57 (1980) 338-39, 368; Friedman, Sharon M., "Blueprint for Breakdown: Three Mile Island and the Media Before the Accident," *Journal of Communication* (Spring 1981) 116-128; David Rubin, "What the President's Commission Learned About the Media" and other articlees in *Annals of the New York Academy of Sciences* 365 (1981) 95-133; and Allan Mazur, "The Journalists and Technology: Reporting About Love Canal and Three Mile Island," *Minerva* 22 (Spring, 1984) 45-66.

As the editors of the journal *Technology Review* later insisted, the main problem for journalists at Three Mile Island was not sensationalism but "the babble of confusion and contradiction within the technological priesthood itself."[18] Covering this confusion -- showing Americans exactly how little nuclear engineers and regulators knew about their own plants -- was, in fact, the most important service the press could have rendered during the disaster. The same can be said of the media's performance during the blackouts and the Bhopal and Chernobyl catastrophes. Democratic societies have often benefited from the disclosure, by unauthorized agents, of information held secret by government or industry bodies.[19] Among these agents are journalists, and disasters can aid them greatly in prying the secrets loose.

Challenges to Technical Authority

To a few, the failure of trained operators and managers to prevent catastrophes like Three Mile Island and Bhopal suggested that the underlying technologies were inherently ungovernable. To many more, it simply exposed the fallacy of officials' repeated claims that they were prepared to handle all emergencies.[20] Because the incompetence on display during each of these events was generally assumed -- or shown -- to extend to the very top levels of the organizations in charge, public confidence in the experts and bureaucracies controlling hazardous systems became another casualty of the disasters we have examined.

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[18] "Technology and the Press at Three Mile Island," *Technology Review* (June/July, 1979) 72.

[19] As demonstrated, for example, by the Pentagon Papers leak and the *Washington Post*'s coverage of Watergate scandal during the nineteen-seventies . I owe this thought to Victor McElheny (Personal communication, June 8, 1994).

[20] As Jack Lemmon, playing a nuclear plant shift supervisor in *The China Syndrome*, asserted, "Hell, we've got quality control that's only equaled by NASA!" -- a line given new impact by the *Challenger* disaster.

Ever since the social and political upheavals of the nineteen-sixties, sociologists and political scientists in the United States have been tracking a general increase in public skepticism toward authority and established institutions.[21] The unsurprising effect of Three Mile Island, Bhopal, and Chernobyl has been to accelerate this trend. The citizen activists mobilized by these and other environmental and health crises, says former EPA administrator William Ruckelshaus, are "the most radicalized group I've seen since Vietnam...They've been empowered by their own demands. They can block things. That's a negative power, but it's real power."[22]

As Winner points out, the role of a large technological organization as the keeper of a public trust -- the provider of some vital service -- is often eclipsed by the imperative for the organization to expand, to increase efficiency and profitability, and to "reverse-adapt" human ends to these new goals. Disasters highlight this conflict, making it difficult for system managers to continue to trade on their reputations as public servants. Even before the 1965 and 1977 blackouts, for example, frequent small outages and the highest electrical rates in the nation had made Consolidated Edison "the company New Yorkers love to hate," but the big power failures brought down a new shower of criticism.[23] "The utility left the public in the care of a control room whose personnel and equipment were not prepared to handle the emergency," the *New York Times* editorialized after the 1977 blackout.

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[21] See, for example, Todd La Porte and Daniel Metlay, "Technology Observed: Attitudes of a Wary Public," *Science* 188 (April 11, 1975) 121-127; Todd La Porte and Daniel Metlay, *They Watch and Wonder: Public Attitudes Toward Advanced Technology* (Berkeley, Calif.: Institute of Governmental Studies, University of California, Berkeley, 1975); Allan Mazur, "Public Confidence in Science," *Social Studies of Science* 7 (1977) 123-25; Allan Mazur, "Opinion Poll Measurement of American Confidence in Science," *Science, Technology, & Human Values* (Summer, 1981) 16-19.

[22] Quoted in William Greider, *Who Will Tell the People: The Betrayal of American Democracy* (New York: Touchstone, 1991) 168.

[23] "Where Were You When the Lights Went On?" *Fortune* (Aug., 1977) 20.

"Inevitably, in times of crisis, the security of the city's electrical lifeline must be left to the judgment of a few key individuals. But there is no excuse for sending them into action ill-prepared or ill-equipped."[24] Critics charged after both failures that Con Ed had abused its monopoly power over the city, and it may only have been the forbidding expense of a public buyout that kept the utility intact.

General Public Utilities, owner of the Three Mile Island plant, came to suffer from its own severe credibility gap -- especially after one vice-president snapped at reporters with the now-infamous line, "I don't know why we need to tell you each and every thing that we do." Publicly-aired disagreements between nuclear experts over the danger of a hydrogen bubble explosion inside the reactor added to the impression of confusion, incompetence, and deception. And the company's unyielding insistence on restarting the Unit 1 reactor, with strong backing from the Nuclear Regulatory Commission, convinced many Pennsylvanians that the nuclear establishment's goal was not to ensure safety but to prevent Three Mile Island from becoming a beachhead for the anti-nuclear movement. It was no wonder that, as one study found, "loss of faith in experts [was] the single most demonstrable psychological impact" for those who experienced the TMI disaster.[25]

Among Indian professionals, the Bhopal catastrophe sparked an angry critique of the managerial and ethical performance of Union Carbide and other multinational corporations doing business in India. At the grassroots level, the disaster mobilized unprecedented resistance to new industrial development, as Du Pont's troubles in Goa demonstrated. In the U.S., however, the real public-image crisis for chemical industry representatives developed only after the 1985 aldicarb oxime leak at Institute, which demolished all assurances that a Bhopal-type accident "can't happen here." Seven years later, a Union Carbide official could still complain that "in spite of the progress Union Carbide and other companies have made [in reducing the frequency of accidental toxic releases], opinion surveys indicate the public isn't buying it one bit."[26]

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[24] "The Control Room That Didn't Control," *The New York Times* (Sep. 10, 1977) 24.

[25] Sandra Prince-Embury and James F. Rooney, "Perceptions of Control and Faith in Experts Among Residents in the Vicinity of Three Mile Island," *Journal of Applied Social Psychology* (Vol. 17, No. 11, 1987) 953-68.

But it was in the post-Chernobyl Soviet Union that the breakdown of technology and the breakdown of authority were most intertwined. The accident exposed the Soviet people to much more than fallout: it also showed them how little the Communist Party cared about their welfare. Striking just when Soviet officialdom was beginning to acknowledge the Party's early atrocities, moreover, Chernobyl came to stand for the whole litany of human and environmental abuses buried in the nation's past: Belomor, Dneprostroi, Magnitogorsk, Kyshtym, collectivization, the draining of the Aral Sea, and so on. Seen alongside their halfhearted attempts to mitigate the accident's impact, Soviet officials' steadfast commitment to nuclear power for almost four years after the catastrophe was particularly galling. The Party's behavior during this time helped teach the Soviet people to tell "truth from lies" and "the honest from the dishonest." Public anger over the government's central role in the disaster contributed greatly to anti-nuclear victories in the 1990 elections, to republican nationalism, and, ultimately, to the undoing of the Communist state. Cleaning up after the environmental damage will, of course, go slowly, since Communism also left the republics bankrupt.

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[26] Ronald Van Mynen, "View from the Top: After the World Changed," *Chemtech* (March, 1992) 135.

Suspicion and mistrust toward authority, it must be admitted, are not the ideal building blocks of democracy -- especially if they degenerate into cynicism and alienation, leading people to opt out of all formal and informal mechanisms of government. As Aristotle wrote, a good citizen knows both "how to govern like a freeman, and how to obey like a freeman."[27] But for people who hope to advance *self*-government, learning to question established systems of technological and political authority is an unavoidable first step. The Pennsylvania woman who complained during the Three Mile Island restart battle that "in the end the little guy just has no say" was expressing a justifiable pessimism. The fact that she and millions like her have ceased to take at face value the assurances of utility and regulatory officials about the safety of nuclear power, however, has helped to bring nuclear plant construction in the U.S. to a virtual standstill. It is in these numerous small acts of resistance -- "plugging up the toilet" of industrial abuses, as ecoactivist Lois Gibbs put it -- that change is born.

Expanding Definitions of Citizenship

The things citizens of modern democracies do -- vote, pay taxes, write to their representatives, fight in their countries' wars, complain about "those bastards in Washington" -- are the same things they have always done. It is the world around these citizens that is constantly changing. Urbanization, professionalization, mass production and mass consumerism, the revolution in transportation and communications, advances in medicine and public health, the growth of a "fifth estate" of scientific and technological experts, the unlocking of the atom and the genetic code: these developments have given rise to political conflicts of a kind the authors of the U.S. Constitution never contemplated.[28] John Kemeny may have been correct in saying that, as a result, "the world has become too complex" for Jeffersonian democracy.[29] But the rubber-stamp model of citizenship Kemeny proposed, with the people and their representatives merely ratifying the recommendations of panels of scientists and engineers, would only exacerbate the problem. What many citizens want today is not a smaller role in government, but a bigger one.

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[27] Aristotle,*Politics*, Benjamin Jowett, trans., in Jonathan Barnes, ed., *The Complete Works of Aristotle*, vol. II (Princeton, N.J.: Princeton University Press, 1984) 2027.

Democracy is more than an abstract ideal to these people. It can mean having real power to protect themselves and their communities from external threats that are, more and more often, technological in origin. As William Greider observes, "A vast network of indigenous environmental organizations has 'popped up' from the grassroots during the last decade...Typically, these people saw their homes or communities threatened in tangible ways. They turned to the government for help and were confronted by bureaucratic indifference or political sleight-of-hand. The disillusionment eventually led them to ask larger questions about power and the nature of democracy, but also to entertain more ambitious conceptions of their own citizenship."[30] Technological disasters, as moments when both technical designs and traditional structures of control and authority are thrown into doubt, can help shape these conceptions and give them velocity.

There are many ways in which people can become more active participants in public life, and we have witnessed a good number of them in this study. The most dramatic instance may have been the political transformation in the Soviet Union, in part the result of public outrage over the Chernobyl disaster. To gain their independence, the people of Ukraine, Lithuania, Belarus, and the other republics literally had to *invent themselves as citizens*, creating an ethic of involved membership in the political community where there was none before.[31] As Jane Dawson noted, "People who had never before considered opposing state policy in any way began to recognize the possibility of participating [in the anti-nuclear movement] and perhaps shaping state policy."[32] Once enough people had made this mental leap from vassaiage to citizenship, the Communist Party's eventual irrelevance and downfall wereguaranteed.

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[28] At the same time, of course, suffrage movements in the modern democracies and in countries like South Africa, the former Soviet Union, and the former Warsaw Pact countries have enfranchised millions of new citizens. Now is the moment to ask *what kinds of new technologies* would best serve these new citizens.

[29] John Kemeny, "Saving American Democracy: The Lessons of Three Mile Island," *Technology Review* (June/July, 1980) 65-75. See Chapter 1.

[30] Greider, *Who Will Tell the People,* 176.

The other disasters studied here sparked subtler reevaluations of the meaning of citizenship. Neither the 1965 blackout nor its sequel in 1977 generated large grassroots political responses, but they served as unplanned exercises in what Winner called epistemological Luddism, temporarily disconnecting people from their sophisticated technological support systems. At least in November, 1965, the result was that New Yorkers were briefly able to see themselves as members of a *polis* defined by people, not by the technological shell they inhabited: "While the city of bricks and mortar was dead, the people were more alive than ever."[33] The lesson of July 13, 1977, was very different; the breakdown of civil order showed people how much they had come to rely upon technology to *avoid* and *deny* their social and moral responsibilities toward one another. But in both blackouts long-suppressed human impulses, whether toward community or toward conflict, expanded to fill the vacuum left by technological failure. Citizenship can be defined as the quality of an individual's response to membership in a community,[34] and the blackouts tested these responses in telling ways.

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[31] A process, however, that is far from complete and whose success is far from guaranteed.

[32] Jane Dawson, *Social Mobilization in Post-Leninist Societies: The Rise and Fall of the Anti-Nuclear Power Movement in the USSR* , 202.

[33] From *The New Yorker* "Notes and Comment" section, 1965, quoted by Lewis Mumford in*The Myth of the Machine: The Pentagon of Power* (New York: Harcourt, Brace, Jovanovich, 1970) 409.

A more traditional indicator of the seriousness with which people view their roles as citizens is the breadth and scale of political activism in a society. Both the Three Mile Island and Bhopal disasters added to the ranks of social movements organized around technological issues. Political scientists have long been interested in the challenge posed to social movements by "free riders," people who are content to benefit from the successes of activist groups without contributing to their efforts,[35] but so many people were moved to join anti-restart groups after Three Mile Island that the real challenge became keeping all of them busy, especially during the drawn-out hearings and court proceedings. Pennsylvanians who had lived through the Vietnam era without so much as writing a letter to their local newspaper were suddenly marching on the TMI plant's gates, traveling to Washington to lobby their senators and representatives, mounting referenda and petition drives, and engaging in civil disobedience.

Prodded by disaster to enlarge their responsibilities as citizens, these new activists were much the same as their counterparts in the Soviet republics after Chernobyl. The difference was that politics in America were supposed to have been democratic from the start. It was indignation over what they had come to perceive as an abridgement of their constitutional rights, rather than the total absence of those rights, that motivated TMI protesters. Fear and the instinct for self-preservation, of course, were also large factors in both cases.

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[34] *Webster's Ninth New Collegiate Dictionary* (Springfield, Mass.: Merriam-Webster, Inc., 1984) 243.

[35] For a discussion of scholarly views on the "free rider" problem in the context of anti-nuclear activism, see Edward J. Walsh, *Democracy in the Shadows: Citizen Mobilization in the Wake of the Accident at Three Mile Island* (New York: Greenwood Press, 1988) 12-13.

Indignation was also a prime element in the movement for right-to-know laws in the U.S. following the Bhopal and Institute accidents. The gas leaks had two related consequences: they left plant neighbors unwilling to trust chemical corporations to monitor the safety of their own practices, and they demonstrated that public ignorance of what went on inside the factory gates meant continued vulnerability to disaster. Both knowledge and responsibility needed to be redistributed, and citizens recognized that some of the burden must fall on them. But as toxics activist John O'Connor recounted, community members were "shocked to find out" that they did not have the legal right to know what kinds of chemicals were used and emitted by manufacturers, or in what volumes.[36] The demand for previously unavailable information about chemical-plant emissions in the form of a national Toxics Release Inventory was the citizenry's way of saying that it wanted to be let in on crucial decisions about safety, health, and environmental quality, no matter how technically complex the issues.

Blunt power confrontations outside the normal channels of representative government can, in fact, involve sophisticated citizen knowledge and political techniques. Knowing that the effectiveness of their movement would depend on their political skills and on their command of the technical issues at hand, many activists at Three Mile Island became self-trained lawyers, public speakers, and experts on nuclear power. The same learning process took place after the creation of the Toxics Release Inventory, which community groups have used to expose (and modify) unsafe and polluting practices at dozens of chemical plants across the United States. All activists must first be students of their chosen subjects, whether this means self-teaching or collaborating with others in an organized citizen's group. This truth greatly widens the scope of citizenship and enriches its practice.

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[36] Personal interview, April 8, 1994.

The domain in which technological disasters have helped to redefine citizenship most, however, is *geography*, or to use the terminology of cultural criticism, "space and place."[37] This category should perhaps have come before everything else I have discussed in this section, since the question of *who* should make decisions about hazardous technologies is almost always the same as the question of *where* these decisions should be made. The harmful effects of technological disasters may be local, translocal, or both, but over the past two decades attempts to assert citizen control over large technological systems have become relentlessly local in focus.

Giddens labels this process, naturally enough, "reembedding": "the reappropriation or recasting of disembedded social relations so as to pin them down (however partially or transitorily) to local conditions of time and place."[38] After a large-system breakdown citizens may feel the need for reembedding particularly acutely:

> All disembedding mechanisms [including large technological systems] take things out of the hands of any specific individuals or groups; and the more such mechanisms are of global scope, the more this tends to be so. Despite the high level of security which globalized mechanisms can provide, the other side of the coin is that novel risks come into being: resources or services are no longer under local control and therefore cannot be locally refocused to meet unexpected contingencies, and there is a risk that the mechanism as a whole can falter, thus affecting everyone who characteristically makes use of it.[39]

Efforts to implement local control in communities where disasters have struck, or might strike, are pleas for a return to the ancient meaning of the word *citizen*: someone having rights and privileges as the inhabitant of a town or city. "Local self-government is a key building block for strong democracy," Richard Sclove explains. "The average citizen can exert much more influence locally than nationally, and local political equality and autonomy provide crucial opportunities for citizens to influence translocal politics."[40] Staking out the community and the local region as the preeminent spheres of popular rule is itself an act of assertive citizenship, one which occurred again and again in the stories we have reviewed.

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[37] See esp. David Harvey, *The Condition of Postmodernity: An Enquiry into the Origins of Cultural Change* (Cambridge, U.K.: Basil Blackwell, 1989), chapter 14: "Time and Space as Sources of Social Power."

[38] Giddens, *The Consequences of Modernity*, 80.

[39] Ibid., 126-27.

The question at issue in the Unit 1 restart battle at Three Mile Island was, in essence, whether the reactor's future would be decided by the communities adjacent to the plant or by a national regulatory bureaucracy that was perceived as largely captive to the industry it regulated. In a town-hall confrontation with NRC representatives, Pennsylvania State Senator George Gekas framed the issue this way: "If someone wants to run a pig sty in our neighborhood, we can collect signatures on a petition to prevent it. If [local citizens] can prevent a pig sty, why shouldn't they be able to stop Three Mile Island?"[41] After Chernobyl, similar questions occurred to the people of Netishin, Shepetovka, Ostrog, and dozens of other towns hosting reactors run by the Soviet State Committee for the Utilization of Atomic Energy. In the Soviet Union, however, even petition drives were outlawed. Environmental clubs founded as chapters of umbrella organizations like Zelenyi Svit served as legitimate "front" groups for activism, allowing local citizens to mount their own assaults against the Soviet nuclear establishment.

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[40] Richard Sclove, "Technological Politics as if Democracy Really Mattered," in Michael Shuman and Julia Sweig, eds., *Technology for the Common Good* (Washington, D.C.: Institute for Policy Studies, 1993) 64.

[41] Walsh, *Democracy in the Shadows*, 68.

To be sure, one cumulative effect of local contests over technological control has been democratization at the national level. Anti-nuclear victories in the Soviet Union fed into the broader movement to throw off state tyranny altogether. Opposition to nuclear plant construction in hundreds of American communities has left the long-term fate of the U.S. nuclear industry in grave doubt -- as it should be, given the state of national opinion on the matter. But many of the national-level legal and economic reforms emerging from technological disasters still hinge on action at the local level. In order to carry out the provisions of the 1986 Community Right-to-Know Act, for example, Congress created a network of local emergency planning committees and charged each with the duty to gather toxic-release data and evacuation plans from local industries and make this information available to local citizens.

There is more to these developments than the old dictum that "all politics is local."[42] Progressive reform now lives in the grassroots. Whereas public interest groups like Common Cause or the Sierra Club once thought it most effective to organize on a national scale and lobby the federal government for sweeping protections, citizens today "skip over government altogether to confront powerful interests bluntly on their own turf," to use Greider's words.[43] One official of the National Wildlife Federation admits that "A reordering of priorities, a rethinking of strategy and tactics is taking place throughout the entire [mainstream] environmental movement because of the increased activism by the very people who are most at risk. Here in Washington it is becoming increasingly obvious that true change will occur at the local level."[44]

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[42] The saying is usually attributed to the late Speaker of the U.S. House of Representatives Thomas P. O'Neill of Massachusetts.

[43] Greider, *Who Will Tell the People*, 157.

The assumption in the U.S. that the state and federal governments are the only qualified agents in society to identify and reduce industrial hazards goes back to the nineteenth century, when inspection bureaus and sunshine laws were created to guard against steamboat boiler explosions, railroad accidents, and the like.[45] Monitoring and challenging government action today, however, is a web of highly vigilant local citizens' organizations who make their voices heard through lobbying, lawsuits, civil disobedience, and other means. According to one political scientist's estimate, there are more than two million citizen groups in the United States, with an active, overlapping membership of some 15 million.[46] The number of Americans who are both attentive to and knowledgeable about technological and political issues is probably not much greater; technologically "attentive" citizens are thought to comprise ten percent of the population, or about 25 million people[47]. But this core of active citizens works and speaks on behalf of many millions more.

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[44] Gerry Poje, chief environmental toxicologist for the NWF. Quoted in Charles Piller, *The Fail-Safe Society: Community Defiance and the End of American Technological Optimism* (Berkeley: University of California Press, 1991) 169.

[45] On the terrible steamboat explosions of the mid-nineteenth century -- "a succession of disasters in kind and scale unprecedented in peacetime experience" -- and the movement for federal regulation they engendered, see Louis C. Hunter, *Steamboats on the Western Rivers: An Economic and Technological History* (Cambridge, Mass.: Harvard University Press, 1949) 271-304, 520-546. See also John Burke, "Bursting Boilers and the Federal Power," *Technology and Culture* (Winter, 1966) 1-23. On the grisly railroad accidents of the same period and the innovative response of Charles Francis Adams' Massachusetts Board of Railroad Commissioners -- known as the "sunshine commission" because it forced disclosure of data on railroad finance, management, and reform -- see Thomas K. McCraw, *Prophets of Regulation: Charles Francis Adams, Louis D. Brandeis, James M. Landis, Alfred E. Kahn* (Cambridge, Mass.: Belknap Press of Harvard University Press, 1984) Chapter 1, especially pp. 25-31.

[46] Karen Paget, "Citizen Organizing: Many Movements, No Majority," *The American Prospect* (Summer, 1990).

[47] For a discussion of "scientific literacy" rates among the U.S. population, see the work of political scientist Jon D. Miller: "Scientific Literacy: A Conceptual and Empirical Review," *Daedalus* 112 (1983, vol. 2) 29-48; "Scientific Literacy in the United States," *Communicating Science to the Public* (Chichester, England: Wiley Publications, 1987) 19-40; "Scientific Literacy," a paper presented to the 1989 Annual Meeting of the AAAS, San Francisco, Calif. (Dekalb, Ill., Public Opinion Laboratory, 1989).

I argued in Chapter 1 that the managers of large technological systems must exercise control over translocal politics in order to hold together their extended technological and bureaucratic enterprises. The result is that citizens have little formal recourse against these systems' unwanted local impacts; as David Harvey puts it, "Those who command space can always control the politics of place."[48] Disasters, however, have the power to push citizens over the line from complacency, resignation, or privatism into radical activism in the interest of local control. "Any struggle to reconstitute power relations is a struggle to reorganize their spatial basis," Harvey writes. The disaster movements studied here have helped bring this struggle into the realm of technological politics.

Technological Citizenship

To have lived in the nineteenth or twentieth centuries is to have witnessed first-hand the seemingly irrepressible influence of technological change on social and political affairs. As Charles Francis Adams wrote in 1867, "It is useless for men to stand in the way of steam-engines" -- expressing the belief, common even then, that industrialization's momentum had outstripped all available means of regulating it.[49] More recently, historians and social analysts have spent much time pondering the "technological determinism" hypothesis, the idea that a historical force arising from the extra-human, volitional qualities of machines fundamentally patterns human existence.[50] Given the difficulties average people face in attempting to assert some reciprocal control over their broad technological environments, it is easy to fall into such a belief.

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[48] Harvey, *The Condition of Postmodernity*, 234.

[49] Charles Francis Adams, "The Railroad System," *North American Review* (April, 1867) 476-511; quoted in Thomas K. McCraw, *Prophets of Regulation*, 8. Adams went on, of course, to prompt Massachusetts to open the modern era of industrial regulation by creating a railroad commission whose purpose was to focus publicity on failures and worker and passenger safety deficiencies.

Technology is not, however, some disembodied power that "drives" history according to its own mysterious logic. It would be more accurate to say that technology *is* history, helping to define in every era the shape of people's activities, expectations, and surroundings, and, in a less significant sense, providing the material cues (waterwheels, plows, locomotives, Victrolas, Model T's, Saturn 5's) which we use to organize our images of the past. Just as the steam engine, the railroad, and the telegraph were the defining technological forms of the nineteenth century, it can be argued that large, complex, failure-prone systems like the electrical grid, chemical factories, and nuclear power plants are the technologies most emblematic of our own times.

From the idea that technology is history, it follows that conceptions of citizenship may slowly change in response to a shifting technological context. The evidence suggests that in the contemporary context -- that is, in societies transformed by the presence of powerful, complex, interconnected technological systems -- *a new form of citizenship is emerging.* Every society has its own ways of encompassing the idea of technology and rendering it a part of social life, whether through politics, philosophy, art, literature, myth, or actual technical practice. Carl Mitcham, an American science-studies scholar, suggests that Western societies have articulated three major ways of understanding technology.[51] The one still dominant today -- a belief in the benevolence of technological progress -- is an inheritance from the Renaissance and Enlightenment eras. I propose, however, that there is also a newer, more critical undercurrent in modern attitudes toward technology, which I will call simply "technological citizenship."

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[50] For useful discussions of the idea of technological determinism, see Langdon Winner, *Autonomous Technology*, 73-88, and Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History? The Dilemma of Technological Determinism* (Cambridge, Mass.: MIT Press, 1994).

This new stance is best defined by comparison to what has come before. The oldest of Mitcham's three ways of understanding technology is the skepticism expressed in legends like that of Icarus and Daedalus and in the sayings of Socrates, Plato, Aristotle, and other ancient philosophers. The ancients believed that technological (i.e. practical, artisanal) activity entailed *hubris* -- the dangerous emulation of the gods -- and led to both personal vice and social disruption. With the coming of the European Renaissance in the fourteenth century and the Enlightenment in the eighteenth, however, the burden of proof shifted from those who favored the introduction of new technologies to those who opposed it. Exemplified by the writings of Francis Bacon, this new philosophy explicitly denied the need for moderation in technological affairs and viewed technology as either morally neutral (and all misuse of it therefore accidental) or inherently virtuous, ministering to physical and social needs that would otherwise go unmet.[52] In reaction to the power and success of the Enlightenment view, finally, came the Romanticism of the nineteenth century. Romantic writers acknowledged the ravages of the Industrial Revolution -- urban blight, unemployment, class conflict, environmental pollution -- but nonetheless rejoiced in their civilization's technological accomplishments. Though the romantics criticized technology's dehumanizing social effects, their fascination with industrialism as an aesthetic phenomenon prevented them from outlining a realistic alternative.

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[51] Carl Mitcham, "Three Ways of Being-With Technology," in Gayle Orniston, ed., *From Artifact to Habitat: Studies in the Critical Engagement of Technology* (Bethlehem, Penn.: Lehigh University Press, 1990) 31-59.

[52] This belief was described in Chapter 1 using the term "meliorism."

Something new and different is afoot today. *The annexation, deliberate or unintended, of decisive political powers by the large, complex technological systems emblematic of the twentieth century -- combined with the fact that these systems' very complexity assures occasional catastrophic breakdowns of technological and political control -- has created both motive and opportunity for the emergence of technological citizenship, a new way of relating to technology.* This view is neither piously skeptical, nor blindly enthusiastic, nor frozen with ambivalence. It is, rather, fundamentally pragmatic, concerned with the business of restoring the democratic political structures modern societies need if they are to cope adequately with constant technological change and with the ever-present danger of disaster.

The idea of technological citizenship, as we have seen it in action here, incorporates elements from the three previous ways of understanding technology while remaining distinct from all of them. "Technological citizens" share with the ancients a constant caution toward technology, but this is not because they place their own trust in abstract nature or providence. Instead, they see themselves as the custodians of their own futures, capable of selecting good or bad technologies, and therefore obliged to evaluate the potential for social and political restructuring implicit in each new invention. Technological citizens make no attempt to hold technology at arm's length or to insulate themselves from technological change, as the ancients did; in this respect their view is more like that of the Enlightenment enthusiasts, acknowledging, even celebrating humanity's irrepressible need to build and innovate. Technological citizens dismiss the Enlightenment belief, however, that every machine that can be built must be built, and they are suspicious of the conviction that "technological progress" automatically improves the human condition.

The technological citizens who have appeared in the foregoing chapters, were they to articulate their attitudes toward technology, might say the following: The gift of technological skill is accompanied by a special responsibility for the integrity of both the physical and the human environments. Complexity is a fact of life in modern technological societies, and we are unwilling to give up the abilities and efficiencies it brings. But if we are to rely on complex technological systems then we must try to understand and monitor them ourselves. We cannot leave these tasks solely in the hands of experts, whether they be operators, designers, corporate managers, or government regulators. We will no longer overlook or tolerate the negative side-effects generated by many technological systems; indeed, there is in this view no such thing as a "side" effect. While nothing in technology is inherently inimical to imagination, emotion, spirituality, freedom, or community, technological activity in the service of aims selected undemocratically can encroach on any or all of these values. Strong democratic participation in the process of shaping the technological order is an effective countermeasure to our current problems, and democracy is also worth promoting in and of itself.

The idea of technological citizenship has much in common with other current concepts on the social shaping of technology, including Neil Postman's portrait of the "loving resistance fighter," Philip Frankenfeld's model of a "new social contract of complexity," and Richard Sclove's advocacy of "technological politics as if democracy really mattered," and so may tap into a general cultural theme that is only now beginning to be expressed.[53] To map the boundaries of technological citizenship, determine whether it is a permanent addition to the political landscape, and ascertain whether it is truly different from older ways of understanding technology, one would need to review more stories of technological disasters and other unanticipated products of technological endeavors and go into more detail about the attitudes and ambitions of the participants (and the bystanders) in local conflicts around scientific and technological issues.[54]

Technological citizenship is only one new variety of citizen mobilization through grassroots political organizing, a phenomenon as old as modernity itself. This is, in fact, one of very few mechanisms people have for adapting to the rapidly changing circumstances of modern life. Giddens believes that there are only four possible "adaptive reactions" to the risks posed by the proliferation of expert systems and other disembedding mechanisms: pragmatic acceptance (a focus on day-to-day tasks, covering an underlying numbness or anxiety); sustained optimism (essentially, the Enlightenment view); cynical pessimism (a humorous or world-weary response); and radical engagement (an "attitude of practical contestation toward perceived sources of danger.")[55] Technological citizenship is one important variety of the fourth reaction, radical engagement, but there are many more venerable examples:

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[53] See Neil Postman, *Technopoly: The Surrender of Culture to Technology* (New York: Vintage Books, 1992) 181-99; Philip J. Frankenfeld, "Technological Citizenship: A Normative Framework for Risk Studies," *Science, Technology, & Human Values* (Autumn, 1992) 459-84; Richard Slove, "Technological Politics as if Democracy Really Mattered," in Shuman and Sweig, eds., *Technology for the Common Good* , 54-79.

[54] There is, of course, a vast literature on scientific and technological controversies, but little of it focuses explicitly on issues of citizenship and democracy. Good starting places are Dorothy Nelkin, ed., *Controversy: Politics of Technical Decisions* (Beverly Hills: Sage Publications, 1979); Allan Mazur, *The Dynamics of Technical Controversy* (Washington, D.C.: Communications Press Inc., 1981); and H. Tristram Engelhardt Jr. and Arthur L. Caplan, eds., *Scientific Controversies: Case Studies in the Resolution and Closure of Disputes in Science and Technology* (Cambrdige, U.K.: Cambridge University Press, 1987).

[55] Giddens, *The Consequences of Modernity*, 136-37.

abolitionism, prohibitionism, feminism, labor movements, civil rights movements, movements for consumer and environmental protections, and so on. Happily, the opportunities for collective organization in modern societies are legion, and the rewards increasingly clear. "Fighting back is a kind of self-interest," as an anti-nuclear activist in one Massachusetts town explains. "It gives us community and identity for the first time."[56]

* * *

"Perhaps we should recognize," writes William McNeill, "that the risk of catastrophe is the underside of the human condition -- a price we pay for being able to alter natural balances and to transform the face of the earth through collective effort and the use of tools."[57] By building systems that exploit the extraordinary speed and power of electronic computers, cybernetic control mechanisms, and complex interconnections, we have unwittingly invited two new kinds of technological hazards, what Wordsworth called "bondage lurking under the shape of good," into our lives.[58] One is the danger of catastrophic technological breakdowns. The other is the danger that large technological systems -- or more precisely, those who design and operate them -- will gain autocratic political control over the societies they are supposed to serve. Serendipitously, however, one of these dangers blunts the other; catastrophe moderates autocracy by cultivating an expanded definition of citizenship. It is regrettable that real disaster is required to initiate and propel this process. But since failures are the inevitable sequels of technological innovation, we would be foolish not to use them to investigate the crucial relationship between catastrophe, control, and citizenship.

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[56] Deborah Katz, panelist, *Knowing Our Place: Challenges to Citizenship in a Technological Age*, Program III: "Democracy, Technology, and the Environment: Public Participation in Scientific Debate and Environmental Policy," a live interactive television program produced by David Tebaldi of the Massachusetts Foundation for the Humanities and broadcast by the Massachusetts Corporation for Educational Telecommunications on May 19, 1994.

[57] William H. McNeill, "Control and Catastrophe in Human Affairs," *Daedalus* (Vol. 118, No. 1, Winter 1989) 1-12.

[58] Quoted in Mitcham, 48.

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